NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Inter-Departmental postgraduate course
GEOINFORMATICS

Design of a 3D multipurpose land administrative system for Greece, in the context of LADM

MASTER DIPLOMA THESIS
Of

KALOGIANNI EFTYCHIA

ATHENS, MARCH 2015

ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ
ΔΙΑΤΜΗΜΑΤΙΚΟ ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ
ΓΕΩΠΛΗΡΟΦΟΡΙΚΗ

ΣΧΕΔΙΑΣΜΟΣ ΠΟΛΥΔΙΑΣΤΑΤΟΥ ΜΟΝΤΕΛΟΥ ΔΙΑΧΕΙΡΙΣΗΣ ΤΗΣ ΓΗΣ ΓΙΑ ΤΗΝ ΕΛΛΑΔΑ ΒΑΣΙΣΜΕΝΟ ΣΤΟ ΔΙΕΘΝΕΣ ΠΡΟΤΥΠΟ LADM

ΜΕΤΑΠΤΥΧΙΑΚΗ ΔΙΠΛΩΜΑΤΙΚΗ ΕΡΓΑΣΙΑ

ΚΑΛΟΓΙΑΝΝΗ Στ. ΕΥΤΥΧΙΑ

ΕΠΙΒΛΕΠΩΝ:
Κάβουρας Μ.
Καθηγητής ΕΜΠ

Εγκρίθηκε από την τριμελή εξεταστική επιτροπή:

Κάβουρας Μαρίνος **Δημοπούλου Έφη** **Κόκλα**
Μαργαρίτα
Καθηγητής ΕΜΠ - Αν. Καθηγήτρια ΕΜΠ Λέκτορας
ΕΜΠ
Διευθυντής ΔΠΜ

ΑΘΗΝΑ, ΜΑΡΤΙΟΣ 2015

Preface

There is an urgent need for land administration system worldwide today and products and services can be offered to users in society from complete digital cadastres. Governments need information to govern. Data integration and accessible information on “people to land relationships” are crucial for sustainable economic and infrastructural development and interrelated spatial planning, for disaster and environmental management. Harmonization of spatial data is a policy in the European Union in support to the implementation of environmental and other policies. Towards this dimension standardization and communication protocols are key concepts.

The increasing complexity of urban (and rural) spaces and their ever-increasing dense and intensive use require proper registration of their legal status (private and public). This registration cannot be provided in all situations by existing 2D cadastral registrations.

Given all this, there are many countries that have already developed their own land administration systems some of them including the third dimension as an important aspect. Towards this development tools are urgently needed taking advantage from modern land administration systems in support to good governance. The data model is one of them as it defines the structure of the spatial and non-spatial information. Land Administration Domain Model (LADM, ISO 19152 2012) provides a generic data model for land administration based on common grounds, widely accepted and being useful for many people countries.

In Greece the Hellenic Cadastre is still an ongoing projects and at the same time it should face and follow the European and international changes and challenges on the domain of land administration. Apart from cadastral information shortage, the country has to deal with the absence of an integrated National Spatial Data Infrastructure. The implementation of an international standard, such as the LADM, is an opportunity for Greece to reorganize its land information registries based on model driven architecture and will set more robust foundations for the completion of the Hellenic Cadastre.

This research investigates several aspects of the associated to 2D and 3D cadastral situations within Hellenic cadastral registration system covering a broader perspective than the one that the Hellenic Cadastre covers today.

Acknowledgements

I could never have finished this work without the support of a group of very pleasant people and I feel privileged that I was able to work with them. I would like to thank all the people who contributed either directly or indirectly to this work. First of all I would like to thank my professor Efi Dimopoulou. Her enthusiasm stimulated me to do this research with great enjoyment and our discussions were very inspiring for me. Peter van Oosterom contributed with his enthusiasm and ideas to further develop this research and encourage me with his ideas to go into depth in some unknown domains for me.

Marinos Kavouras and Margarita Kokla contributed to the research by introducing the necessity of the creation ontology and by discussing the further improvements of this research. The NCMA S.A. cooperated in this research by multiple discussions on data models and on research developments, as well as the explanation of the existing situation and progress of the Hellenic Cadastre.

Finally there are a number of people who supported me in finishing this thesis in a more indirect way. To have these people around me give me the possibility to explore and experience the things in life that are essential to me. First of all I would like to thank my family; Stavro, Anastasia, Olympia-Christina and Lefteri as they always support me in doing what I find important to do.

Secondly, I would like to thank all my inspiring friends who contributed to the thesis with some way. My sister Olympia-Christina did a great job because she gave me advice on the English text of this thesis. Eva and Dimitris also contributed to this thesis by discussing my findings using their 3D modeling and juridical expertise correspondingly. Katerina and Mirela assisted me in preparing the illustrations in this thesis. Stathis was indispensable during my research because he was always available assisting me in all kinds of technical issues. These contacts were very important to me during my research.

Table of contents

List of figures

List of diagrams

List of tables

Abstract

Nowadays, most countries have developed their own land administration system. Some countries operate deeds registration, other title registration. Some systems are centralized, and others decentralized. Some systems are based on general boundaries approach, others on fixed boundaries. However, many of those countries lack a coherent national approach to land administration, which constitutes an essential component of national administrative portfolios.

Modern cadastral systems and in general, land administration systems, were affected and continue to be strongly affected by the advancements in Information and Communications Technology. Significantly, GIS, DBMS and in particular spatial DBMS, as well as other systems for spatial analysis (e.g. R) and visualization systems allow for more effective management and dissemination of spatial and non-spatial information nowadays.

The use of land is always related to a certain amount of 3D space as well as a certain amount of time, e.g. leasehold. However, traditionally cadastres are based on representations of the division of the land in 2D on a certain moment in time. Because of growing pressure on land and rising land values, which lead to more complex and intensive land use, it is argued that there will be a growing need for 3D/4D information in cadastral registers. As the 2D maps cannot sufficiently represent the reality, the 3D Cadastre has been introduced especially for the description of apartment units and for physical objects that cross above or below land parcels and other types of multilevel buildings. Even when the creation of property rights to match these developments is available within existing legislation, describing and depicting them in the cadastral registration poses a challenge. Additionally, the upcoming 3D approach in other domains (3D GIS, 3D planning, etc.), which makes a 3D approach of cadastral registration technologically realizable also causes a growing interest for the realization of a 3D Cadastre.

The scope of a 3D cadastre depends on each country and its limitations and opportunities. To ensure legal security and support development, a 3D cadastre can benefit from other domains that develop towards 3D and vice versa, since 3D data can be exchanged. However, those capabilities cannot be fully exploited due to the absence of standardization and interoperability within cadastral systems.

Nowadays standardization has been an increasingly accepted process in the fields of land management and land registries all over the world. In the developed world, standards are required in land administration for adequate information exchange and data acquisition. At the European level, INSPIRE directive identifies 34 different geo-information themes, including cadastral parcels, which should be (and currently are) harmonized.

At a national level now, the design and development of the Hellenic Cadastre is an ongoing project since 1995, progressively replacing the existing mortgage registries. Due to the current financial crisis, there is a delay in the process of the Hellenic Cadastre, but it is expected to be accomplished by 2020. The dynamic nature of immovable property in Greece calls for updated information about rights and restrictions that apply to each land parcel.

Taking this situation into account, there is a need to standardize the process of land management, introducing a model for the effective management of the properties in Greece with a multipurpose character. Therefore, in Greece, it is time to plan for the future, chart a course for redefining the data model of the HC and replacing components of the existing system. A new data model could facilitate the provision of data to internal and external users in a more flexible

format for the community's needs. That means improving the structure of property rights, restrictions and responsibilities, as well as all relative stakeholders, in a direction of harmonizing with international land administration systems and standardization processes in this field.

Land Administration Domain Model, ISO 19152, was introduced as a model to create standardized information services in an international context, where land administration domain semantics have to be shared between regions or countries, in order to enable necessary translations. It covers land registration and cadastre in a broad sense by describing spatial and administrative components, source documentation and the ability to link with external registrations. The model also includes agreements on data about administrative and spatial units, land rights in a broad sense and source documents (e.g. titles, deeds or survey documentation). The rights may include real and personal rights as well as customary and informal rights and the restrictions and responsibilities can be similarly represented to document the relationships between people and land.

This thesis proposes a comprehensive LADM country profile for 2D and 3D cadastral registration system for Greece. The proposed model is partly based on the existing spatial and administrative registration systems, and partly based on new developments inspired by the LADM standard and other country profiles. Within the country profile, an attempt is made to cover all Greek land administration related information, which are maintained by different organizations today. This means that apart from the registrations of the existing HC, other objects are categorized and registered in the proposed model aiming at the creation of a multipurpose land administration system for Greece.

The different types of spatial units include areas with archeological interest, buildings and unfinished constructions, utilities (legal spaces), 2D and 3D parcels, mines, planning zones, Special Real Property objects usually found in Greek islands (anogia, yposkafa) and marine parcels. What makes the development of this model unique is the support of a wide range of spatial units, each of them having different requirements. The country profile also includes the content of various code lists, which are an important aspect of standardization.

It should be mention that as I am currently doing two Master Degrees, one at the National Technical University of Athens and one at Technical University of Delft, I decided to choose a broad topic for my research in order to be able to split it into two parts for my 2 thesis and also go into to depth in one domain. For that reason, the broader topic that was selected was the link between the legal with the physical reality of 3D objects through the derivation of a technical model from a conceptual one using international standards. In particular, the conceptual model created during this thesis describes mostly the legal part of the 3D objects registered in the proposed multipurpose land administration system but also provides different ways to link it with the physical counterparts of the objects. This conceptual model will be the input for the TUDelft MSc thesis, which will be more technically oriented, according to the character of the Master. In particular, a prototype to derive a technical model from the conceptual will be developed by implementing it into a spatial database and visualising the result in a 3D environment using advanced and complete technical tools.

Περίληψη

Σε παγκόσμιο επίπεδο τα σύγχρονα κτηματολογικά συστήματα και γενικότερα τα συστήματα διαχείρισης γης επηρεάζονται από τη ραγδαία εξέλιξη της τεχνολογίας των πληροφοριών και τηλεπικοινωνιών. Παρόλες τισ διαφορές των συστημάτων ανά τον κόσμο, η ανάπτυξη των Συστημάτων Γεωγραφικών Πληροφοριών, των συστημάτων διαχείρισης βάσεων δεδομένων και πιο συγκεκριμένα, χωρικών βάσεων δεδομένων, καθώς και άλλων εργαλείων χωρικής ανάλυσης (π.χ.R), επιτρέπουν την καλύτερη διαχείριση και διάχυση των χωρικών και μη-χωρικών δεδομένων.

Τα τελευταία χρόνια η έρευνα στον τομέα της διαχείρισης γης επικεντρώνεται ολοένα και περισσότερο στην ενσωμάτωση της τρίτης διάστασης, τόσο στην εγγαφή και αποθήκευσή της, όσο και στην οπτική αναπαράστασή της. Σήμερα, η τρίτη διάσταση κρίνεται ιδιαίτερα σκόπιμη και απαραίτητη στην απεικόνιση της περίπλοκης πραγματικότητας που έχει δημιουργηθεί κυρίως στον αστικό ιστό των πόλεων λόγω των πολλαπλών και επικαλυπτόμενων χρήσεων γης αλλά και των επικαλυπτόμενων εμπράγματων δικαιωμάτων. Οι δυνατότητες εφαρμογής ενός τρισδιάστατου κτηματολογικού συστήματος έχουν μελετηθεί εκτενώς τόσο σε επίπεδο έρευνας αλλά και πλέον με την εφαρμογή πιλοτυικών προγραμμάτων σε διάφορες χώρες (π.χ. Ρωσία, Κίνα).

Ένα ολοκληρωμένο τρισδιάστατο κτηματολογικό σύστημα πρέπει να περιλαμβάνει κτηματολογικά δεδομένα που απεικονίζονται σε τρεις διαστάσεις και να λαμβάνει υπόψιν θεσμικές, νομικές και τεχνικές πτυχές ανάλογα με τα ιδιαίτερα χαρακτηριστικά της κάθε χώρας. Παρόλες τις προσπάθειες των τελευταίων ετών δεν υπάρχει κάποιο ολοκληρωμένο τρισδιάστατο κτηματολόγιο σε κάποια χώρα του κόσμου.

Κρίσιμο ρόλο σε αυτή την κατεύθυνση διαδραμτίζουν η τυποποίηση και μοντελοποίηση των συστημάτων αυτών καθώς και τα προτόκολλα επικοινωνίας που επιτρέπουν τη δυνατότηα ανάπτυξης τέτοιων συστημάτων καθώς και τη διαλειτουργικότητά τους. Διάφορες προσπάθειες τυποποίησης καταβάλλονται τα τελευταία χρόνια με σκοπό να βρεθούν τα κοινά σημεία των κτηματολογικών δεδομένων, οι ανάγκες τους και να αρθούν οι γεωγεαφικοί, πολιτικοί και κοινωνικοί περιορισμοί.. Σε μια προσπάθεια τυποποίησης τα ιδιαίτερα χαρακτηριστικά αλλά και οι ανάγκες της κάθε χώρας δεν παραμερίζονται, αλλά προτείνονται γενικά πλαίσια και δομές όπου κάθε σύστημα μπορεί να συμπεριληφθεί και να δώσει έμφαση στις ανάγκες του, επιτρέποντας όμως την επικοινωνία και διαλειτουργικότητα με άλλα.

Στο διεθνές σκηνικό επικρατεί τα τελευταία χρόνια μία σειρά πρότυπων μοντέλων (ISO) η οποία βασίζεται στη σύνδεση του προσώπου με το ακίνητο μέσω των δικαιωμάτων, περιορισμών και υποχρεώσεων. Το Land Administration Domain Model (LADM), αποτελεί τη μεγαλύτερη, μέχρι σήμερα, προσπάθεια τυποποίησης και μοντελοποίησης των κτηματολογικών συστημάτων σε διεθνές επίπεδο. Αναμένεται να αποτελέσει διεθνές πρότυπο μέχρι το Δεκέμβριο του 2012. Καλύπτει τις κοινές διεθνείς αντιλήψεις σχετικά με τη διαχείριση της γης, στηρίζεται σε προηγούμενα διεθνή πρότυπα και είναι ευέλικτο και εύκολα προσαρμόσιμο ανάλογα με τις ανάγκες της εκάστοτε χώρας.

Στην Ελλάδα, όπου το Εθνικό κτηματολόγιο είναι υπό εξέλιξη, τα ελληνικά κτηματολογικά δεδομένα σταδιακά εντάσσονται σε ένα πολυδιάστατο κτηματολογικό σύστημα το οποίο θα αποτελέσει το πλέον σύγχρονο σύστημα καταγραφής ακινήτων, εμπράγματων δικαιωμάτων και συναλλαγών γης. Παρόλα αυτά, το μοντέλο που χρησιμοποιεί το ΕΚ δεν βασίζεται σε κάποιο διεθνές πρότυπο, αλλά έχει δημιουργηθεί ώστε να εξυπηρετεί τις ανάγκες της χώρας. Για το λόγο αυτό,, υπάρχει η ανάγκη να ενταχθεί σε ένα ευρύτερο,

τυποποιημένο πλαίσιο που θα επιτρέπει τη διαλειτουργικότητα και επικοινωνία μεταξύ όλων των εμπλεκόμενων φορέων τόσο εντός, όσο και εκτός Ελλάδος.

Λόγω της πολυπλοκότητας του αναγλύφου της χώρας και των ιδιαίτερων μορφολογικών χαρακτηριστικού που οδηγούν και σε ιδιαίτερο ιδιοκτησιακό καθεστών, στην παρούσα διπλωματική εργασία προτείνεται ένα πολυδιάστατο μοντέλο διαχείρισης γης. Πιο συγκεκριμένα, προτείνεται ένα μοντέλο διαχείρισης γης που επιτρέπει την εγγραφή τόσο δισδιάστατων όσο και τρισδιάστατων δεδομένων για την Ελλάδα, βασισμένο στο διαθνές πρότυπο LADM, ISO 19152. Γίνεται μια προσπάθεια ομοδοποίησης και καταγραφής όλων των δεδομένων που σχετίζονται με τη διαχείριση της γης και διαχειρίζονται από διάφορους φορείς. Πέρα από τα δεδομένα που εγγράφονται σήμερα στο Κτηματολόγιο και άλλα δεδομένα κατηγοριοποιούνται και καταγράφονται αποσκοπώντας στη δημιουργία ενός πολυδιάστατου συστήματος.

Η ποικιλομορφία που εμφανίζεται στα χωρικά δεδομένα της χώρας κατηγοριοποιήθηκε ως εξής στο προτεινόμενο πολυδιάστατο μοντέλο: στους διάφορους αρχαιολογικούς χώροιυς τα κτίρια και τις υπό-εξελιξη κατασκευές, τα δίκτυα κοινής ωφέλειας, τα δισδιάστατα και τρισδιάστατα γεωτεμάχια, το θαλάσσιο γεωτεμάχιο, τα ειδικά ιδιοκτησιακά αντικείμενα που εμφανίζονται κυρίως στις Κυκλάδες, τα ορυχεία, αλλά και οι κατευθύνσεις που απορρέουν από τα διάφορα επίπεδα χωροταξικού σχεδιασμού. Η ποικιλομορφία των διαφόρων ειδών χωρικών μονάδων αλλά και επλεκόμενων φορέων σε συνδυασμό με τις ανάγκες που διαμορφώνουν, καθιστούν το παρόν μοντέλο μοναδικό. Τέλος, στο μοντέλο προτείνονται ορισμένες λίστες κωδικών για κάθε μία από τις κλάσεις στις οποίες καταγράφονται οι διάφορες τιμές που μπορεί να πάρει το κάθε πεδίο. Η κωδικοποίηση που προτείνεται για τις λίστες κωδικών είναι σημαντικό χαρακτηριστικό της προτυποποίησης.

Τέλος, θα ήθελα να αναφέρω πως παράλληλα με το ΔΠΜΣ Γεωπληροφορική παρακολουθώ και το μεταπτυχιακό πρόγραμμα Geomatics στο Πανεπιστήμιο Ντέλφτ της Ολλανδίας (TUDelft). Καθώς τα δύο μεταπτυχιακά βρίσκονται στον ίδιο ερευνητικό τομέα απόφάσισα να επιλέξω ένα ευρύτερο θέμα έρευνας το οποίο θα μπορούσα να διαχωρίσω σε δύο μέρη, ένα για τη μεταπτυχιακή μου εργασία στο ΕΜΠ και ένα για το TUDelft. Οι δύο εργασίες είναι ανεξάρτητες μεταξύ τους, αλλά και συνέχεια η μία της άλλης. Το θέμα που επέλεξα είναι η διερεύνηση της σύνδεσης της φυσικής με τη νομική πλευρά των τρισδιάστατων αντικειμένων μέσω της έρευνας των διαφόρων τρόπων που μπορεί να εξαχθεί ένα τεχνικό μοντέλο που περιγράφει τη φυσική διάσταση των αντικειμένων από ένα ενοιολογικό που περιγράφει τη νομική διάσταση.

Πιο συγκεκριμένα, η παρούσα μεταπτυχιακή εργασία περιγράφει το σχεδιασμό ενός εννοιολογικού μοντέλου με πολυδιάστατο χαρακτήρα για την Ελλάδα. Το αποτέλεσμα θα αποτελέσει τη βάση για τη μεταπτυχιακή εργασία στην Ολλανδία, όπου θα διερευνηθούν οι διάφοροι τρόποι που μπορεί να εξαχθεί ένα τεχνικό μοντέλο από το ενοιολογικό. Στη συνέχεια, το τεχνικό μοντέλο θα εισαχθεί σε μία χωρική βάση δεδομένων (PostGIS) και τέλος, θα υπάρξει μια οπτική αναπαράσταση της φυσικής και νομικής πλευράς των αντικειμένων σε τρισδιάστατο περιβάλλον. Η συνέχεια της εργασίας αυτής στο TUDelft ήταν ο βασικός λόγος για τον οποίο το κείμενο αυτό γράφτηκε στα αγγλικά.

Abbreviations

ADE	Application Domain Extension
AJAX	Asynchronous Javascript and XML
API	Application Programming Interface
BIM	Building Information Model
bSI	Building Smart International
CAD	Computer Aided Drawing
C.C.	Civil Code
CDM	Cadastral Data Model
CityGML	City Geography Markup Language
CSF	Community Support Framework
CWA	Closed World Assumption
DBMS	Data Base Management System
DCDB	Digital Cadastral Data Base
FIG	International Federation of Surveyors
GII	Geo-Information Infrastructure
GLTN	Global Land Tool Network
GMMI	Greek Mining/Metallurgical Industry
HC	Hellenic Cadastre
HMGS	Hellenic Military Geographical Service
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
ILA	Israel Land Authority
IFC	Industry Foundation Classes
INSPIRE	Infrastructure for spatial information in Europe
IR	Implementing Rules
ISO	International Standardization Organization
KAEK	Hellenic Cadastre Code Number
KML	Keyhole Markup Language
LandInfraDWG	Land And Infrastructure Domain Working Group
LADM	Land Administration Domain Model
LAS	Land Administration System
MDA	Model Driven Architecture
MPC	Multipurpose Cadastre
NCMA	National Cadastre Mapping Agency
NL	The Netherlands
NTUA	National Technical University of Athens
OGC	Open Geospatial Consortium
OMG	Object Management Group
OWA	Open World Assumption
OWL	Web Ontology Language
R & D	Research and Development
RDBMS	Relational Data Base Management System
RIF	Rule Interchange Format
SD	Sustainable Development
SDI	Spatial Data Infrastructure
SDO	Standards Developing Organization
STDM	Social Tenure Domain Model
SQL	Structured Query Language

SWRL	Semantic Web Rule Language
TUDelft	Delft University of Technology
UBM	Unified Building Model
UML	Unified Modeling Language
VGI	Volunteered Geographical Information
W3C	Word Wide Web Consortium
XML	eXtensible Markup Language

The increasing complexity of urban and rural spaces and their intensive use the last years require proper registration of their legal status. Until now this registration cannot be provided by 2D cadastral registration and 3D Cadastre is considered to be the solution. Significant progress has been made in advancing the concept of 3D cadastres and related technologies to facilitate its realization.

1. Introduction

1.1. Motivation and background

In many global documents, land is considered as an issue of utmost importance, see for example Agenda 21 [UNCED, 2002]. It is considered as the ultimate resource, for without it life on earth cannot be sustainable [United Nations, 1996]. Many political objectives are in many ways related to access to land and land – related opportunities. How governments deal with this issue, developing multiple land policies is an interesting topic and many studies have been conducted through this direction. However, apart from the land policy, the tools to facilitate its implementation are very important and challenging [Lemmen, 2012].

Until today, many countries have developed their own land administration systems [LAS], which fit in the purposes and needs of its society. Most of the countries based their LAS on existing standards, while some others developed their own methodology in order to organize the people to land relationships, e.g. Greece. A good LAS should service the needs both of the individual and of the community at large. Standardization is a key concept in designing of LASs and in supporting data quality by avoiding inconsistencies.

According to Lemmen [2012], land administration systems must deliver accessible, exchangeable, complete, and valid information about people to land relationships in 2D and 3D reflecting various ownership models and they must manage the huge amount of information in cadastral databases.

Moreover, during the last two centuries population density has increased considerably making land use more intense. This trend has caused a growing importance of ownership of land, which has changed the way humans relate to land. This changing relationship necessitated a system in which property to land is clearly and indisputably recorded [Stoter, 2004].

Digital 3D cadastres can be the solution as they provide important and reliable information for different aspects of land and property management, provide to decision makers and may be utilized as the basis for the integration with other information models, such as Building Information Model, CityGML, etc. [Rajabifard et al., 2012].

From all the above mentioned, pve. This was the motivation for starting this reaserach at the field of 3D Cadastres, mainly investigated the case of Greece.

The overall research can be described as the design of a multipurpose model for land administration in the context of international standards. The aim of this research is to exolicitly describe the legal reality of the objects and their inter-relationships by creating a conceptual model for land administration in Greece based on LADM ISO 19152, focused mainly on the third dimension. The conceptual model is a proposal covering a broader perspective than the one of the HC today as it also includes objects and interests that are not registered to the existing HC. It aims to best organize the current situation and also include improvements for the future. The objects, interests and their relationships are described by using UML diagrams.

1.2. Setting the scene

The last decades urbanization is regarded as a global trend. World urban populations demand apartments and high-rise structures nowadays. In 2013, more than 3.5 billion people, about half of the world's population, live in cities. Many demand a smarter cross-disciplinary integration in the land development industry including architecture, construction, surveying and building management disciplines. This includes integration along the supply chain, better documentation and design, the use of technologies and effective communication [Kalantari, 2014]. It is clear that the ways societies use and occupy space occur in multiple dimensions; however, the ways we manage and administer space relies on two-dimensional information representations (2D).

Residential developments also arguably drive an accompanying need for investment in infrastructure and services such as laying utilities (networks, underground cities, large shopping complexes, subterranean transport systems, etc.). As spatial entities, these developments impact on the urban form, with corollary impacts on urban flow (e.g. energy, travel, etc) and function (e.g. land use) [Salat & Bourdic, 2012]. Therefore, there is need for information about all aspects of the built form to facilitate better decision-making to support the functioning of our cities.

Complex cities demand 3D description and they are initiatives worldwide that suggest we are moving in this direction. For instance, at European level, INSPIRE directive [INSPIRE, 1997] defines that the cadastral parcel has a more visible role now in facilitating multiple aspects of land information management and emphasizes the 3D aspect of the buildings. However, there are clear opportunities for exploring how best to position 3D cadastres as part of much needed collaborative approach [Rajabifard, 2014].

Greece is consisted of many complex cities that need 3D cadastral registrations. Due to the unique morphology and the great diversity on the terrain but also on the way the properties have been built, the 2D registrations are not enough to describe this situation. At the moment, the Hellenic Cadastre is an ongoing project and proposals for best managing the special, unique cases are important.

The land question in Greece presents great diversity and specificities, as it largely depends on localized historical, geographical, economic, social, political and cultural factors. It is a challenge to face and exploit with the optimal way those characteristics of Greece, using international experience and create a model for land administration covering a broader scope than the one that the Hellenic Cadastre covers today.

1.3. Research approach

In this section the research objectives and questions as well as the research methods that were used to achieve these objectives and answer these questions, are explained.

1.3.1. Research objectives

The main objective of the thesis is to answer the question how to design a multipurpose cadastral model for Greece based on international standards. The emphasis of the thesis is on the creation of the conceptual model, based on the ISO 19152 Land Administration Domain Model (LADM).

To realize this objective, the thesis concentrates on three main topics:

- **Analysis of the background.** This part explores the following scientific fields:
- What is the state-of-the-art on the 3D Cadastres? International experience in this field.
- What is the need for 3D Cadastres?
- How can the standardization help towards this direction?
- International country profiles for LASs based on ISO 19152.
- **Hellenic Cadastre**. In this section, the state of the art for the Hellenic Cadastre will be presented. Moreover, the cases that 3D Cadastre is required at the Greek territory will be emphasized. The different cases should be treated with specific and legally regulated way. In addition, the way that the Hellenic Cadastre deals with those situations today will be explored.
- **Proposed model for land management in Greece based on LADM**. At the last section, the proposed model based on the international standard ISO 19152 will be presented and described by UML diagrams.

1.3.2. Methodological approach

In order to answer the research question and objectives the following methodological approach is followed.

- **Analysis of the background.** A literature review is performed on relevant papers and theses related to this issue. During the past decade, various 3D cadastre activities have been conducted and numerous developments have occurred with respect to 3D cadastres. After past research and prototype developments the present era is one in which the first 3D cadastral systems are in operation [Van Oosterom, 2013]; those developments are described in the section. This development brings additional experience and forms the basis for new requirements as well as new research challenges. Towards this direction, the importance of standards and communication protocols are analyzed and the recent and most important on the domain of land administration are presented. LADM, ISO 19152, providing an abstract, conceptual schema, defines a formal description of a common set of concepts and terms and was selected among other standards as basis for the proposed model in this research. Therefore, characteristic LADM country profiles that emphasize the 3D extension and serve needs of different countries are presented and discussed.
- **Hellenic Cadastre.** The National Cadastre and Mapping Agency S.A. company (from now on NCMA) is a Legal Entity of Private Law and its mission is the study, development and operation of the Hellenic Cadastre. It collects information on property objects, in order to cover the entirety of the Greek territory and according to its action plan, this information is in reference with the land-parcel and is analyzed on the two dimensions of the real objects. In this section the role and the operation and the progress of the HC are described and also the data model used today is presented. However, registering property objects in the three-dimensional has become an imperative need in order to optimal reflect all optimal complex cases of the multilayered reality of property rights. Especially in urban built-up areas where the third dimension will display the allocation of ownership rights in the vertical component sufficiently. However, implementing the 3D concept in the present

Cadastral system does not imply the establishment of an absolute three-dimensional registration system, which is not currently feasible. Greece has many special cases that require 3D registration and representation and they are explored in this section; for instance the Special Property Right Objects (SPRO) are presented together wit they way they are faced today.

- **Proposed model for land management in Greece based on LADM.** For the last section, the matching the HC data model classes with the corresponding of the LADM is presented. The in-house data model of NCMA is not based on international standards and the proposed model based on ISO 19152 is a research proposal with a broader perspective than the HC. Today, the NCMA S.A. develops a system based on land parcels of the country, including their geometric description and ownership status as well as additional information needed for administrative, technical and economic activities. The proposed model, apart from this information, includes the zoning plans, the parcels with archeological interest separately, the utility networks as well as the marine parcels, which today are not registered in a cadastral system. The scope of this model is to create a 3D multipurpose system where all the geographical information that can participate in a transaction will be registered, grouped and managed optimally. Therefore, the classes of the conceptual model are described together with the corresponding code lists for each class. Extra attributes and external classes are added in order to represent the Greek reality. For the creation of the code lists deep investigation of the existing situation took place and then values are added to represent the future developments. Last but not least, the concept of levels at the conceptual model is introduced, in order to better organize the information in thematic coherent groups.

1.4. Overview of the thesis

Chapter 1 (this chapter) presents the motivation and background of this research, specifies the objectives and the scope of it and presents the methodology approach that was followed. The second chapter introduces the concepts of land administration and cadastre, the 3D cadastre and the different aspects of it. Additionally, the related research that has been conducted for 3D Cadastres is revised, emphasizing at the need for the third dimension and discusses the state-of-the art and the future trends of the data storage, data visualization and semantic information in 3D.

The next chapter gives an overview of standardization process in the field of land administration the last years. Different standards are presented and their need is described. The research focuses more on ISO 19152 LADM, its structure and the reasons, which lead to its selection as basis for the development of the Greek profile.

Moreover, at the fourth chapter the international experience in this field is presented. In order to place this research in an international context, several characteristic country profiles based on LADM - mostly focused on 3D- are described.

Chapter 5 includes an overview of the Hellenic Cadastre project. The organization, the data model that is now used for the registration and maintenance of the cadastral information and the progress of the outgoing project for completing the HC are described. The last part of this chapter deals with the characteristic cases in Greece that require three-dimensional visualization, which enables their location on, below or over the earth's surface.

Last but not least, in chapter 6, the proposed model for a 3D multipurpose cadastre for Greece is presented. In the beginning, the matching the HC data model classes with the corresponding of the LADM is presented. The scope of this model is to create a 3D multipurpose system where all the geographical information that can participate in a transaction will be registered, grouped and managed optimally. Therefore, the conceptual model is described in UML diagrams and its classes are described together with the corresponding code lists for each class.

Finally, conclusions and recommendations for further development are presented at the last section and emphasis is given at proposals for the implementation and test of the performance of this model.

Part I

Analysis of the Background

2. Related research in 3D Cadastres

2.1. Cadastre and Land Administration

Driven by sustainability and economic objectives, many cities around the world are moving towards complex vertical multi-unit and multi-functional developments [e.g. King, 2004; Adam, 2008, 2012]. Operationally, this adds an additional layer of complexity to the management of these structurally complex buildings. Consequently, these developments and their RRRs challenge current land administration practices, particularly where the management of RRRs is based on the concept of a land parcel [Ho, 2012].

In response to the complexities of understanding and managing contemporary urban spaces, creation of new land administration systems utilizing 3D technologies and 3D digital information has increased. It is clear that according to the local situation, the land market requirements, the legal framework, and technical possibilities and limitations of each country, cadastre and LAS are defined and used in different ways.

In this section, useful definitions of cadastre, land administration and land administration systems are further clarified.

2.1.1. Land administration

All countries have to deal with governing the land. The operational management concept is the range of land administration function that include the areas of [see Figure 2.1]:

- Land tenure [securing and transferring rights in land and natural resources],
- Land value [valuation and taxation of land and properties],
- Land use [planning and control of the use of land and natural resources] and
- Land development [implementing utilities, infrastructure and construction planning].

The four functions interact to deliver overall policy objectives and they are facilitated by appropriate land information infrastructures [cadastral and topographic datasets, etc.] and supported by sophisticated Information and Communication Technology (ICT) models [FIG, 2014]. Across land administration literature, there is widespread acknowledgement that land administration systems [LAS] reflect the relationship that people have with land.

The term Land Administration was defined by the Nations Economic Commission for Europe to be "the processes of determining, recoding and disseminating information about the tenure, value and use of land when implementing land management policies. It is considered to include land registration, cadastral surveying and mapping, fiscal, legal and multi-purpose cadastre and land information systems". It is recognized that land administration and LASs are state responsibilities, but there can be many areas where the private sector is involved. [UNECE, 1996; Lemmens, 2012].

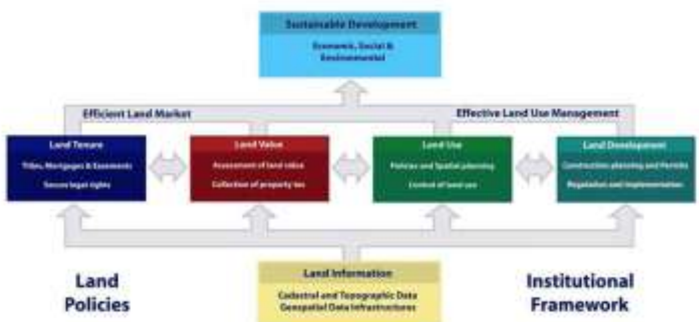


Figure 2.1: A global land management perspective [Williamson et al., 2010].

Land administration is defined as the process run by the government using public or private sector agencies related to land tenure, land use, land development and land value, according to Williamson et al. [2010]. LASs are essential for land management. They are considered as an infrastructure for implementation of land management policies in support of sustainable development.

As shown in Figure 2.2, the ultimate objectives of land administration are sustainable development using current land policy and the corresponding instruments. This determines how a government can provide access to land, offer tenure security, regulate the land market, implement land reform, protect the environment and levy land taxes [Adeniran, 2014].

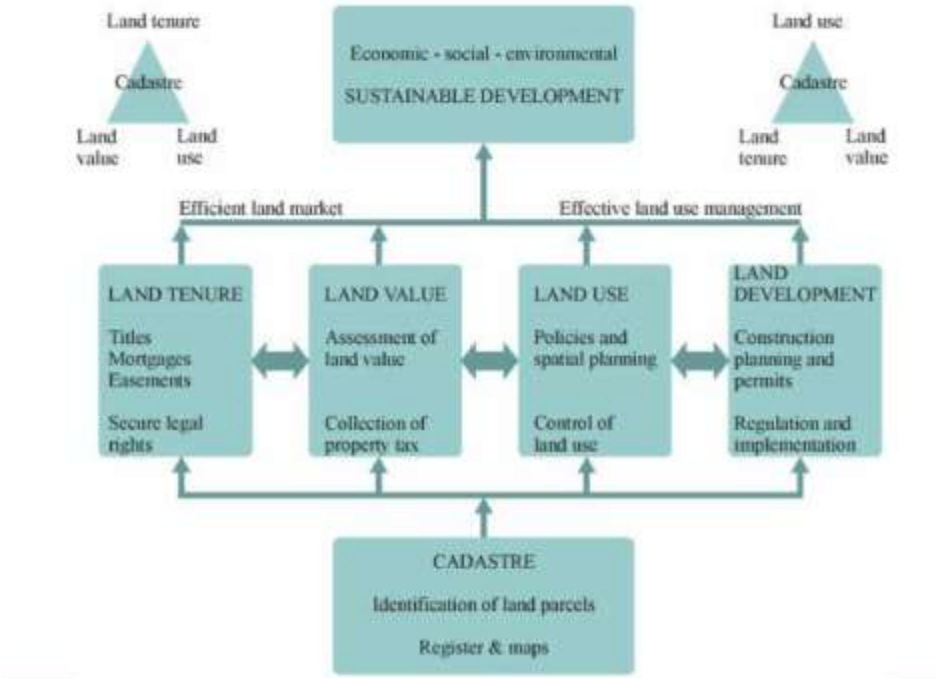


Figure 2.2: Global land administration perspective [Adeniran T., 2014].

In most less developed countries the legal framework for land administration reflects colonial times and often serves only the elite. The processes for land registration are complex, costly, time consuming and with high demands for accuracy of boundary surveys. The existing legal framework is therefore often a significant barrier for implementing a flexible approach to building land administration systems and the underlying spatial framework.

The spatial framework is the basic large-scale mapping showing the way land is divided into smaller spatial units for specific use and occupancy. It provides the basis for dealing with land administration functions such as: recordation and management of legal and social tenure; assessment of land and property value and taxation; identification and management of current land use; planning for future land use and land development; delivery of utility services; and administration and protection of natural resources.

The Social Tenure Domain Model (STDM) supports the continuum of land rights. It is flexible and enables all legal and social tenure rights to be captured [FIG/GLTN, 2010].

In conclusion, it has to be emphasized that as LAS covers land registration and cadastre. The combined process is called land administration and a LAS is the environment in which this process takes place. Processes include adjudication [the juridical and technical procedures to document land rights], establishment of and transaction on land rights and information provision. Information provision can support in multiple purposes: taxation, legal or tenure security, support of land market and mortgage industry, spatial planning and other [Bogaerts & Zevenbergen, 2001; UNECE, 1996].

2.1.2. Cadastre

The definition of a cadastre has long been associated with a function as a repository of land and property related information (e.g. the Austro-Hungarian cadastre and the Napoleonic cadastre of the 19th century), whose original functions as tools of survey and census to produce registers of information are still relevant today. Definitions of modern cadastres however, are perhaps more aligned with the content of the information itself and its technological implementation. For example, Figure 2.3 [left] below shows the cadastre as a concept comprising individual pieces of information relevant to land and property, and the implementation of this concept is through the use of technology to link, integrate and visualize land and property information. At the right side, the individual pieces of information are exploited using the technologies required to support the physical representation of cadastral information in 3D.

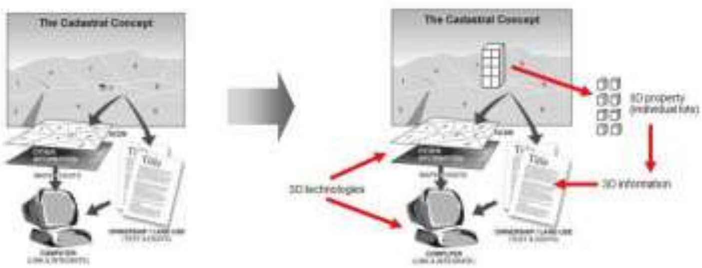


Figure 2.3: The cadastral concept [FIG, 1995] and the adapted 3D cadastral concept [Ho et al., 2013].

Simpson [1976] refers to the cadastre as "*a public register of the quantity, value and ownership of the land (immovable property) in a country, compiled to serve as a basis for taxation*". A register of deeds is a "*public register in which documents affecting rights in land are copied or abstracted*".

Apart from Simpson [1976] there is a common agreement that a cadastre can be used for different purposes. This means that both a legal administrative component and a geometric component are included.

According to Henseen [1995] land registration and cadastre have the following meaning.

- *Land* is an area of the surface of the earth together with the water, soil, rocks, minerals and hydrocarbons beneath or upon it and the air above it.
- *Land registration* is a process of official recording of rights in land through deeds or as title on properties. It means that there is an official record [land register] of rights on land or of deeds concerning changes in the legal situation of defined units of land.
- *Cadastre* is a methodically arranged public inventory of data concerning properties within a certain country, based on a survey of their boundaries. Such legal land objects are systematically identified by means of some separate designation. They are defined either by private or by public law.

The cadastre as an engine of LAS is shown in Diagram 2.1. The diagram highlights the usefulness of the large-scale cadastral map as a toll by exposing its power as the representation of the human scale of land use and how people are connecter to land [Williamson et al., 2010].

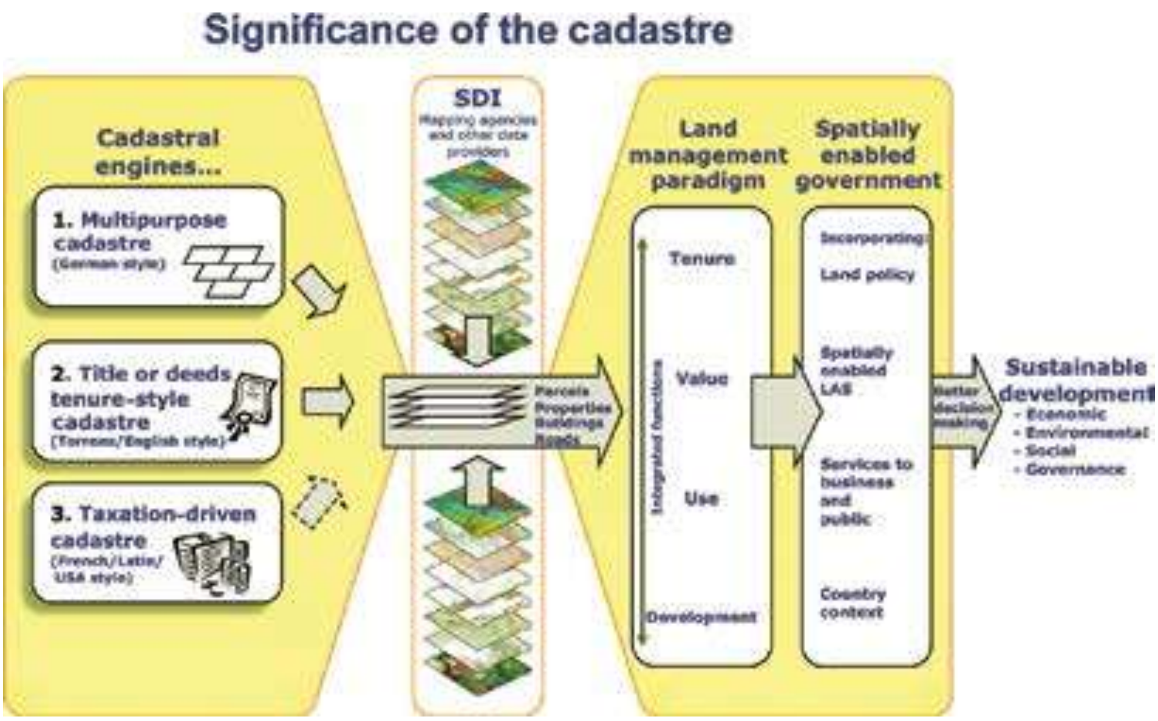


Diagram 2.1: The "butterfly" diagram shows the cadastre as the engine of LAS and the means to implement the land management paradigm. The cadastral information forms a key component within the SDI as it supports each of the four land administration functions for delivery of sustainable development [Williamson et al., 2010].

The cadastre is defined as a register of land information by FIG [FIG, 1995]. This means that a cadastre is a parcel based and up-to-date land information system (LIS containing a record of interests in land (rights, restrictions and responsibilities). Additionally, it usually includes a geometric description of the parcel linked to other records describing the nature of the interests, the value of the parcel, and improvements on that, etc. [Lemmen, 2012].

Kaufmann and Steudler [1998] state that "Cadastre 2014", is a worldwide-recognized vision on Cadastre. Cadastre 2014 can give the answers to the questions of *where and how much and who and how*. It is mentioned that Cadastre 2014 can replace the traditional institutions of "Cadastre" and "Land Registration" as it represents a comprehensive land recording system.

To be able to meet all these requirements, the main tasks of current cadastres can be defined as:

•To **register the legal status** of and governmental restrictions on real estate: the persons who have interests in land; what the interests are [nature and duration of rights, restrictions and responsibilities]; on what land the interests are established [information on parcels such as location, size, value];

•To **provide information on the legal status** of and governmental restrictions on real estate.

To sum up, it has to be emphasized that LAS is a tool, or a number of tools that covers land registration and cadastre. This combined process is called land administration, which includes the establishment of, and transactions on land right and the juridical procedures to document property, use and other land rights [Lemmen, 2012].

2.1.3. 3D Cadastre

The ways society use and occupy space occur in multiple dimensions. However, the ways we manage and administer space relies on two-dimensional information representations. The legal ambiguity and administrative limitations inherent in such practices are becoming increasingly pronounced within land administration especially for urban areas. In response, a research domain has emerged, termed by specialists as *"3D Cadastres"*, to seek greater correspondence between the administration of legal land and property (parcel) boundaries and the reality of physical bounds of structures themselves [Kalantari & Stoter, 2013].

This research domain in this field is concerned with the "*registration of the legal status in complex 3D situations*" [FIG, 2012]. Within the International Federation of Surveyors (FIG) 3D cadastres' working group, the concept of 3D cadastres with 3D parcels is applied in the broadest possible sense in order to comprise all the country-specific meanings of 3D Cadastres. Consequently, 3D parcels include land and water spaces both above and below the surface. However, each country should decide according to the needs and the legislation framework the types of the 3D parcels that should be registered [Van Oosterom, 2013].

The implementation of a 3D cadastre model in a country requires generation of 3D volumes representing either physical objects or volume parcels based on cadastral data [Stoter & Van Oosterom, 2006]. According to FIG [2010], a 3D parcel is a legal object describing part of the space, often related with a physical object that is also described in 3D with plane coordinates. In order to generate 3D real properties plane coordinates, real property units' dimensions and semantic data are required. The realization of 3D cadastral models also requires sufficient elevation data, and therefore, cadastral legislation should introduce height measurement methods and requirements for 3D Cadastre modeling, e.g. Navraril & Unger [2011]; Sanecki et al., [2013].

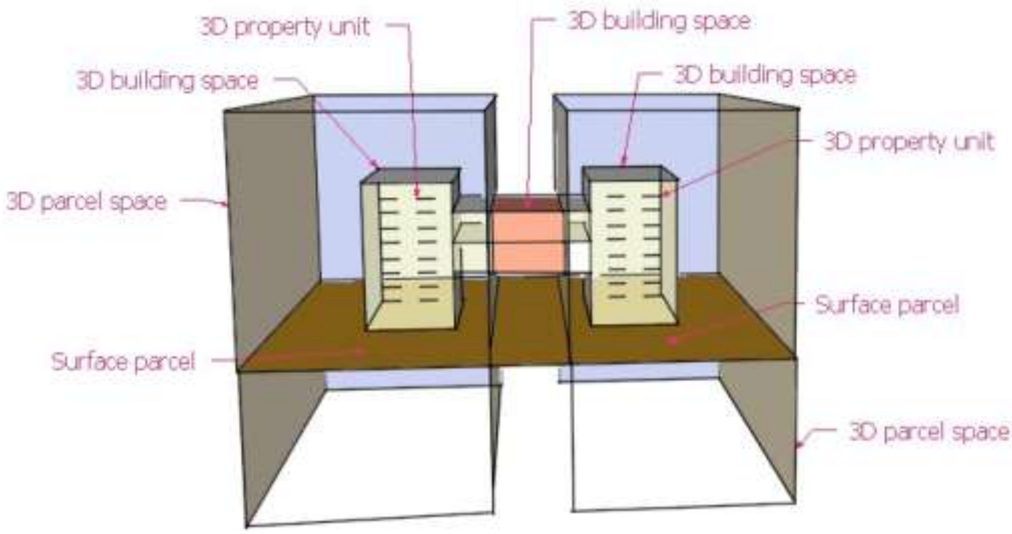


Figure 2.4: Different 3D spaces in 3D cadastre [Ying et al., 2011].

Ying et al. [2011], introduce two conceptual classes to describe 3D space in China represented by 3D solid; the 3D land parcel and the 3D building space, as shown in Figure 2.4. A 3D (legal) building space unit can be associated with a physical construction and the description of the legal space focus on the homogeneity of the legal attributes [Karki et al., 2010].

According to the literature, real property is defined as either a real or an ideal part of space, which constitutes an autonomous or an undivided multiowned property right. It can be argued that all property units are in fact three-dimensional, since a (2D) property unit may not consist solely of the land surface, but extends downwards into the earth and upwards into the sky. Thus, the three-dimensional aspect of the property does not concern the actual extent of the property unit, but rather the delimitation of it. It is therefore difficult to define the term 3D property, as noted in Paasch and Paulsson [2011].

3D property is often used as a general comprising term and the content of it differs between countries in their legislation. One description of it is real property that is legally delimited both vertically and horizontally [Paulsson, 2007]. The concept of 3D property is therefore still a rather new form of land management, as it only exists only for a decade. However, there has been an increased interest in 3D property and ownership apartments, although the demand has not been as high as initially expected. The use of 3D property formation in land management is still to be seen as a supplement to the traditional 2D property formation [El-Mekawy et al., 2014].

There are many obstacles towards the adoption and use of the concept of 3D property. Today, many countries have regulated or plan of regulating their legal and cadastral framework to accommodate 3D property issues. Although approaches concerning 3D property in each country differ, they share similar principles [Paulsson, 2012; Kitsakis & Dimopoulou, 2014].

For this research, 3D parcels will refer to 3D spatial units with right, restrictions and responsibilities attached to it, where ownership parcels should not overlap other ownership parcels [Van Oosterom et al., 2011]. This definition is different from the classical one, according to FIG [2011], where the land parcel is denoted as a piece of 'land' with defined boundaries, on which a property right of an individual person or a legal entity applies.

The implementation of each one of the different types of 3D Cadastre models, serving the unique needs of each country, requires generation of 3D volumes representing either physical objects or volume parcels based on cadastral data [Stoter & Van Oosterom, 2006].

According to Kitsakis and Dimopoulou [2014], data that may be used to generate the 3D model of legal spaces and physical objects are presented, respectively in

Table 2.1 and

Table 2.2:

LEGAL OBJECT	Data	Remarks
Location	• Planar coordinates [X, Y] on cadastral maps/databases given in national reference systems.	Earth's surface elevation is not always available/ is in low accuracy/ is in different coordinate systems.
RRR Definition	• Planar coordinates [X, Y] on cadastral maps/databases given in national reference systems. • Descriptevely in	

	contracts/deeds	
"Spatial Extents"	• Descriptevely in contracts/deeds. • Survey drawings.	Isometric plans [3D] available in Common Law jurisdictions.

Table 2.1: Data required representing legal spaces in 3D, [Kitsakis & Dimopoulou, 2014].

PHYSICAL OBJECT [PO]	Data	Remarks
Parcel Location	Planar coordinates [X, Y] on cadastral maps/databases, mineral cadastres available in national reference systems.	• Varying accuracy, • Scanned or paper drawings may exist.
PO Location	Building footprints are recorded to the cadastral maps/databases in national reference systems.	• Varying accuracy, • Scanned or paper drawings may exist.
PO Dimensions	Horizontal and vertical dimensions are available on building permit drawings	No coordinates available.
PO constituent parts	• Can be found in building permit drawings. • In descriptive form in contracts/deeds	No coordinates available.
Elevation and height data	• PO's relative heights can be obtained from cross section drawings. • Surfaces heights in most countries not recorded directly.	• 3D drawings mainly in Common Law jurisdictions and the Netherlands. • Z coordinates reduced to national reference systems.
Infrastructure, utility networks	Drawings, maps from utility owner, operator.	Data cannot be easily obtained.

Table 2.2: Data required representing physical objects in 3D [Kitsakis & Dimopoulou, 2014]..

<u>Condominium and strata titles</u>

"Condominium" comes from Latin. *Domus* means, "house" and *dominum* is the "lord or owner of the house". Therefore *dominium* signifies power or ownership (of a house). *Con* means "with". Hence *condominium* means "ownership [of a house] with" [http://www.beforeyoubuyacondo.com/condovsstrata.html].

According to the UN/ECE Guidelines, condominium ownership comes in a variety of forms from multi-apartment buildings used exclusively for residential purposes to those that contain both residential units and space used for commercial purposes. It is a type of home ownership that allows an individual to own an individual unit in a large complex. The people who purchase these units own each and everything inwards from the boundary - which is the walls of their unit. The common areas include areas such as elevators, swimming pools, hallways, and other amenities that may be available.

They may extend vertically as in tower blocks or horizontally as in terraced houses. Essentially such buildings have two components - privately owned units and jointly owned parts [for example service areas and equipment such as lifts, electricity and heating supply, etc.].

The right in freehold to a separate apartment in a tower block breaches the idea that land, as real property, extends from the center of the Earth to the infinite of the sky. The concept that the land is a single unitary object may work in legal theory but in practice it needs to be modified, especially in the case of ownership of individual apartments in a block of flats [UN/ECE, 2004].

"Strata" is also derived from Latin, but its origin is a little more obscure. Originally, *stratum* meant, "spread", but by the time we see it associated with condominiums in English, it was perhaps borrowed from geology where it is used to describe a layer in a rock formation. The plural of *stratum* is *strata*: "layers".

Apparently the Australian [New South Wales] legal profession adopted "strata" in 1961 to cope with a new form of co-ownership of apartment blocks since such buildings have two or more "layers" or "strata". So an owner of a Lot and undivided co-ownership in the common property was granted a "Strata Title".

A few years later, British Columbia appropriated the term and much of the legislation from Australia, naming the first act the *Strata Titles Act*. As with the Australians the term "strata" was extended to include townhouse type and bare land developments. Essentially, there is no difference between the terms condo and strata, unless you reside in Australia or British Columbia in Canada, where the term has encompassed townhouses within it [http://geniepad.com/posts/204-what-is-the-difference-between-condo-strata-hoa-and-co-op-associations].

Those differences on the terminology, depending on the legislation framework of each country or area show that the need for a common terminology in the domain of land administration is urgent.

Apart from the condominiums there are also other special cadastral types related to 3D; for instance the marine cadastre, which is described below.

Marine Cadastre

The interests of a nation do not stop at the land-sea interface. They continue into the marine environment. Therefore, the responsibilities and opportunities of governments to provide infrastructure for land and resource management extend to marine areas. This has brought with it an increased need to more effectively and efficiently manage marine resources to meet the economic, environmental, and social goals of sustainable development [Williamson et al., 2010].

The concept of the marine cadastre evolved to bring coherence to the various approaches. The design of the marine cadastre was influenced by the environmental movement and its effect on politics and society; by emerging technologies for realization and visualization of marine information and boundaries; and by the need to deliver regional, rather than merely national, marine management. [Williamson et al., 2010]. The marine cadastre poses a whole range of questions, due to the different nature of the environment. The most important issues are: the inherently 3D nature of most marine rights, which makes a 2D definition of these rights legally inadequate, the fourth dimension of spatial data, the overlapping rights exist within a single locality [Sutherland, 2005a]. So the marine cadastre can be considered as a special case of 3D Cadastre [Sutherland, 2005a; Sutherland, 2005b].

The concept of a marine cadastre is being considered by a number of countries, in order to address the issues and problems. Due to the complex and changing nature of the marine environment, there are currently several different definitions for a marine cadastre. Robertson et al., [1999] describe the marine cadastre as:

"*A system to enable the boundaries of maritime rights and interests to be recorded spatially managed and physically defined in relationship to the boundaries of other neighboring or underlying rights and interests*".

Nichols et al., [2000] have a different understanding of the marine cadastre, introducing concepts of ownership and the need to record rights and responsibilities together with the boundaries. They describe the marine cadastre as:

"*A marine information system, encompassing both the nature and spatial extent of the interests and property rights, with respect to ownership, various rights and responsibilities in the marine jurisdiction*".

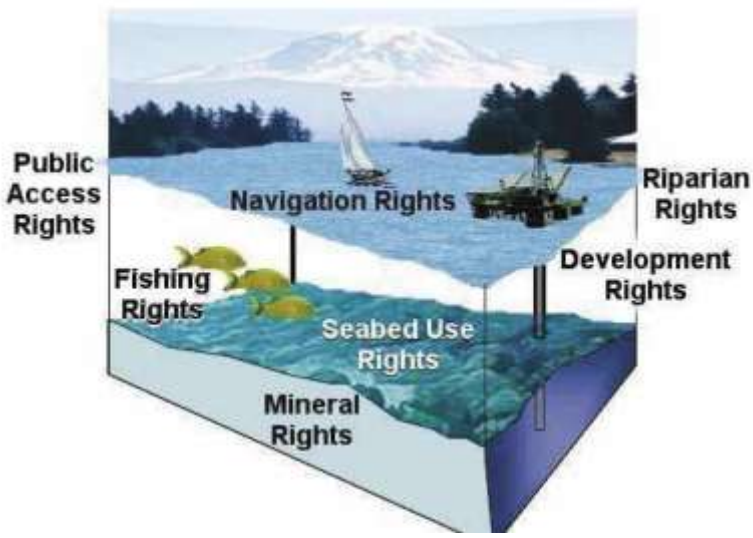


Figure 2.5: The marine parcel [Sutherland, 2000].

The concept of a marine cadastre is being considered by a number of countries. In order to illustrate the relationship and interaction between marine rights and responsibilities, Sutherland [2000] has developed a conceptual diagram of the complex set of rights and controls offshore, showing the overlapping nature of relationships between stakeholders and the 3 dimensional nature of the ocean [Figure 2.5].

Also a marine property model has presented by Ng'ang'a et al. [2004] [Diagram 2.2. Since 1999 [Hoogsteden et al., 1999] the concept of marine cadastre has been present in Geomatics-related research and professional literature. There is a plethora of articles and papers on the subject of marine cadastre that deal with varying technical, institutional, legal and stakeholder issues. To name a few; Binns & Williamson, 2003; Fraser et al., 2003; Ng'ang'a et al., 2004; Fulmer, 2007; Nichols et al., 2006; Sutherland & Nichols, 2009; Rahibulsadri et al., 2014.

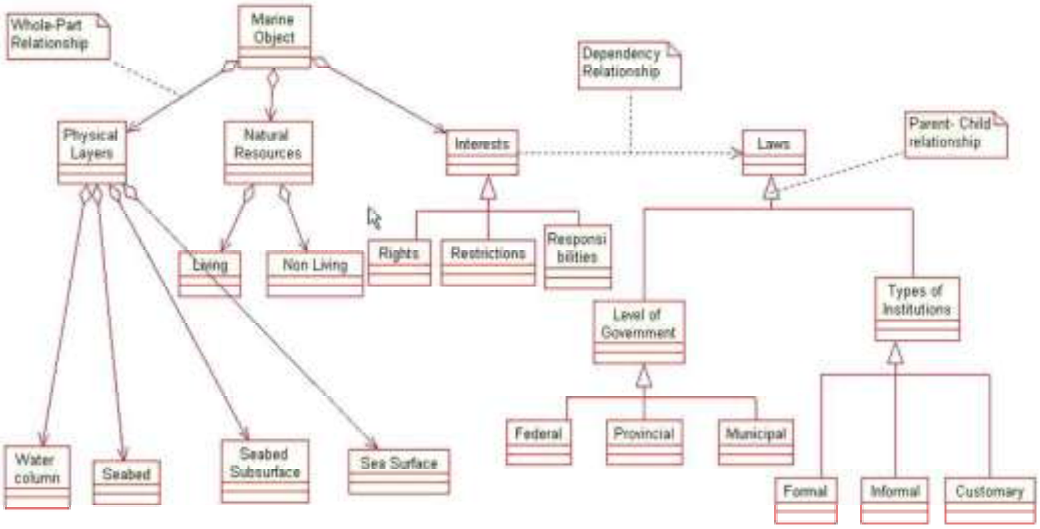


Diagram 2.2: Marine property data model [Ng'ang'a et al., 2004].

2.2. Why 3D??

For 3D developments above and below ground, such as apartments, tunnels, bridges, utilities networks, etc. a 2D land parcel is no longer the appropriate basic spatial component of cadastral models for managing and modeling 3D information [Aien et al., 2013]. It should be replaced by 3D property object, as 2D cannot represent the complexity of 3D properties.

The increasing complexity of infrastructures and densely built-up areas requires a proper registration of the legal status of real properties; both private and public. 3D properties allow the real property to be volumetrically delimited as discrete legal entities. It is a volume of space on, above or below the ground that defines and represents a particular right, restriction or responsibility [RRR] [Aien et al., 2013].

Current cadastral data models only represent legal objects, and do not integrate their physical counterparts. This trend is working well in 2D cadastres where the land parcels (legal objects) represent the corresponding physical land boundaries as well.

However, in 3D cadastres objects are represented by physical structures such as walls, floors, and ceilings in the buildings, and are integrated so that the cadastral data model facilitates management and representation of 3D legal objects. This integration also maximizes the usability of 3D cadastres for additional applications such as property management and city space management [Aien et al., 2013].

It is important to realize that legal objects do not necessarily coincide with their corresponding physical objects mostly in cases of airspace and common properties [Lemmen, 2012]. In this case, a 3D cadastre can be used to reveal the differences between the two 'aspects' of the object and the consequences of that.

In this scope, a 3D cadastre can interact with other registrations, which offers opportunities, such as: the holders of infrastructure constructions will benefit from a clear registration of the location of the objects, since they have more legal protection and better overview of other RRRs that may intersect. Moreover, the parties may be motivated to include more spatial information in the deeds when enabling 3D registrations.

Moving a step forward, the time dimension is required to be able to recorded how the legal status of the objects changes during the time. In most cadastral registers, the time is representing by a versioning of the objects depicted by time-stamps that usually indicate the creation and the deletion of the object in the cadastral database, see Figure 2.6 [Döner et al., 2011].

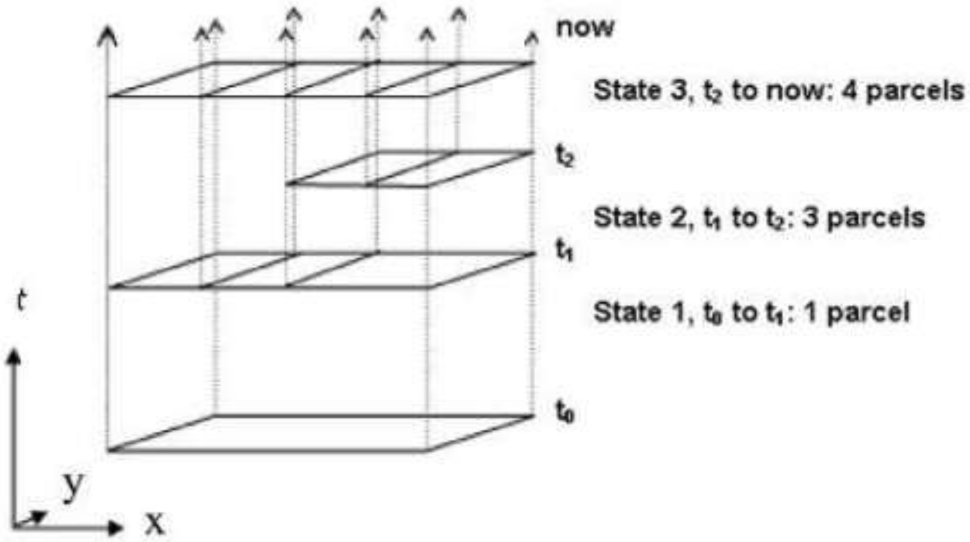


Figure 2.6: Temporal concept - changes of state of a subdivision [Döner et al., 2011].

In addition to the above mentioned, there are other drivers to move from 2D and paper-based representation methods to 3D visualization of the cadastre.

These include [Shojaei et al., 2013]:

- **Technology push**: there are a rapidly increasing number of 3D visualization systems in many disciplines providing realistic representations of the world with real-time navigation;
- **Public demand:** as people demand more access to information about their environment, they require effective means of communication that do not require specialized training;
- **Professional demand:** nowadays, 3D visualizations are widely used in various applications such as architecture, urban planning, building development, and disaster management. Professionals are looking for compatible visualization systems for also managing ownership information in 3D;
- **Resource efficiency:** land and property, as important resources, require modern management approaches for their sustainable use, especially in populated urban areas; and
- **Systems efficiency:** 3D visualizations increase the functionality of a cadastre [Stoter & Van Oosterom, 2006].

Therefore, there is a need for effective and efficient systems for representing RRRs in 3D. Such a system has several parts: a data model for the information itself [Aien et al., 2013], a data format to support the data model, a database to manage data, and visualization tools for communicating, exploring, and representing the information.

2.2.1. What is the role of 3D Cadastre in the full life cycle in 3D?

When considering the complete development life cycle of rural and, in particular, urban areas, many related activities should all support 3D representations. The exact definition of these activities differs from country to country, and their order of execution may differ.

However, in some form or another, the following steps performed by various public and private actors, which are all somehow related to 3D cadastral registration, are recognized, according to Van Oosterom [2013]:

1. Develop and register zoning plans in 3D.
2. Register [public law] restrictions in 3D.
3. Design new spatial units/objects in 3D.
4. Acquire appropriate land/space in 3D.
5. Request and provide [after check] permits in 3D.
6. Obtain and register financing [mortgage] for future objects in 3D.
7. Survey and measure spatial units/objects [after construction] in 3D.
8. Submit associated rights [RR]/parties and their spatial units in 3D.
9. Validate and check submitted data [and register if accepted] in 3D.
10. Store and analyze the spatial units in 3D.
11. Disseminate, visualize and use the spatial units in 3D.

Several of the above mentioned activities and their information flows need to be structurally upgraded from 2D to 3D representations. Because this chain of activities requires good information flows between the various actors, it is crucial that the meaning of this information is well defined.

It is important to reuse existing standards as a foundation and to continue from that point to ensure interoperability in the domain in our developing environment!

2.3. Needs and opportunities for 3D Cadastre

A little more than a decade ago, Stoter and Ploeger [2002] stated that there is competition for space, especially in the cities, with increasing population and more advanced space-demanding activities that have to share space within the same traditional two-dimensional property unit. Many complex situations where there is a need to separate the ownership within an existing parcel and its space can be found [Stoter & Ploeger, 2002].

The use of 3D property rights has for many years been a tool for providing secure and lasting rights for the use of space and has become a common feature internationally [see e.g. Paulsson, 2007]. In order to efficiently manage these complex situations of ownership - and other RRRs associated with land, water and air - the procedures for 3D property formation and registration also have to be addressed.

According to previous studies and the community needs, digital 3D cadastres can provide important information for different aspects of land management. The information related to land and the owners is complicated, sometimes even insufficient and difficult to keep on track. Cadastres with 3D information facilitate registration of 3D property rights and represent the spatial extent of ownership boundaries in the third dimension of height where layered and stratified ownerships exist. Residential multi-unit and high-rise developments and complex apartments are becoming more and more popular, as they accommodate people and businesses. [Aien et al., 2013].

Especially in metropolis with dense population, the development of land use has promoted the land parcels to be subdivided in 3D space according to certain property rights. This results in 3D parcels above or below the land surface and the management of that becomes an urgent task for the government of each country [Ying et al., 2011].

In addition, they support land development processes including issuing of permit plans in dense urban areas, which cross above or under other developments. Last but not least, they can be used as a basic layer to integrate with other information layers such as 3D city models (e.g. CityGML), Building Information Model (BIM), transportation, utility networks, land use, and delivery of services for different applications providing reliable information for decision makers.

Moreover, pressure on land in urban areas has led to overlapping constructions [Figure 2.7 and Figure 2.8]. Cities require significant infrastructure above and below the ground in unique titles and arrangements, Even that the existing legislation can serve in a way the matching of these developments with the corresponding property rights; the cadastral registration still remains a challenge [Stoter, 2004].

Figure 2.7: Business district 'La Defense' in Paris, a road and a metro in the subsurface intersect buildings and plazas [Stoter, 2004].

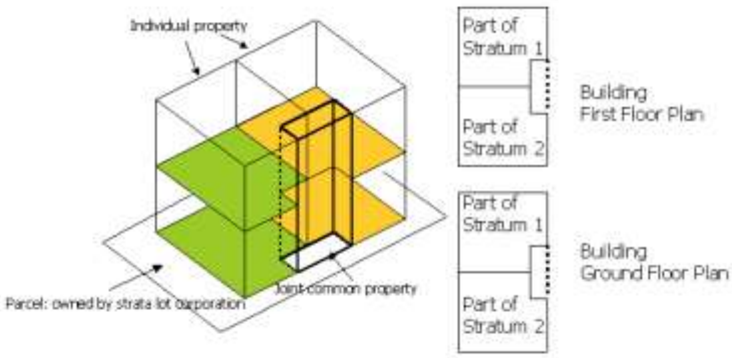


Figure 2.8: Example of drawing in strata titles [Stoter, 2004].

In addition, 2D survey plans [even with stratum boundaries specified] are no longer able to represent the reality of the inter-related titles or deeds with their complex rights, restrictions and responsibilities [see Figure 2.10]. On the other hand, tooltips to display attribute data [Figure 2.9] are very useful for the representation of RRRs.

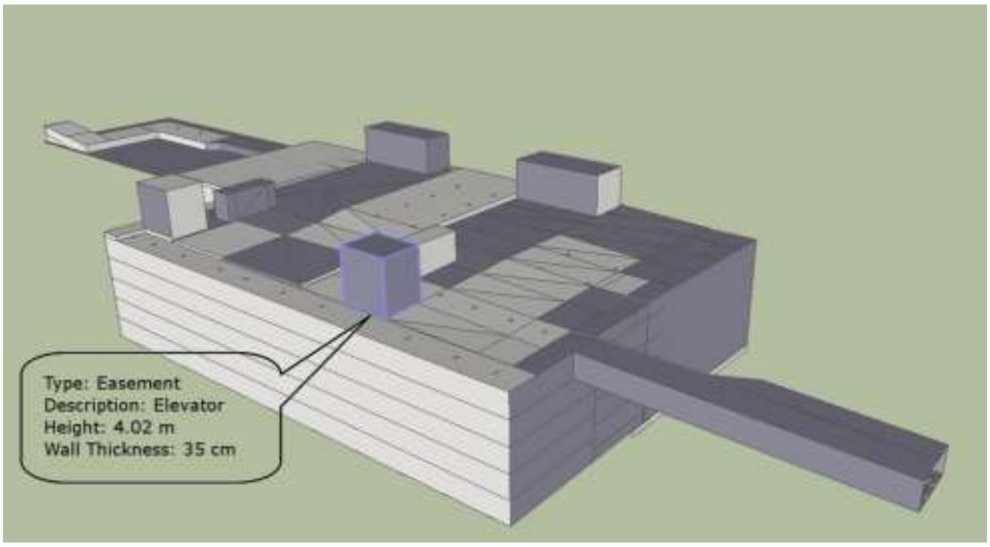


Figure 2.9: Tooltip to display attribute data [Shojaei et al., 2013].

Figure 2.10: High rise building and its 2D representation in a land subdivision plan [Rajabifard et al., 2012].

The complexities described above are not new. However, they have become more obvious the last year. This is due to the fact that complex buildings and in general 3D situations have been occurring much more often the last decades than previous years. For instance, the number of pipelines and cables has grown, many tunnels and highway intersection have been built and the complexity of multi-purpose constructions has increased rapidly.

Taking also into account that people today want to know and have ensured the legal status of the property through registrations and demand high-accuracy in the boundaries; the need for a 3D cadastre is urgent.

According to Stoter [2004], the basic needs for a 3D cadastre can be summarized as:

- To have a complete registration of 3D rights. Rights that entitle persons to volumes, explicitly.
- To have a good accessibility to the legal status of stratified property including 3D spatial information, as well as restrictions at the legislation framework.

The scope of a 3D cadastre depends on each country and its limitations and opportunities. To ensure legal security and support development, a 3D cadastre can benefit from other domains that develop towards 3D and vice versa, since 3D data can be exchanged.

A link with external databases containing objects of interest for the cadastre [monuments, forest protection zones, etc.] is needed. The update on the external databases should be synchronized with the cadastral database in order to avoid loss of information and inaccuracies. Linking different registrations and linking different databases can be established by the set-up of a well-working national Spatial Data Infrastructure (SDI).

2.4. Conceptual models of 3D Cadastres

Stoter J. [2004] introduced three concepts to register 3D situations, depending on the way that the term "3D cadastre" can be interpreted ranging from a full 3D cadastre supporting volume parcels to the current situation with limited additions of 3D information. The three proposed conceptual models are:

2.4.1. Full 3D cadastre:

Introduction of the concept of rights in 3D space. Rights and restrictions are explicitly relates to volumes, defined in three-dimensional space. This situation requires change in the legislation, technical and cadastral framework. Two alternatives are distinguished for the full 3D cadastre.

- Alternative 1: Combination of infinite parcel columns and volume parcels. - Combined 2D/3D alternative. This requires conversion of the conventional representation of parcels into 3D. Two types of real estate objects are distinguished: infinite parcel columns [which still apply in 2D] and volume parcels.
- Alternative 2: only parcels are supported that are bounded in three dimensions [volume parcels]. - Pure 3D cadastre. The only real estate object is the parcel volume [bounded in all dimensions].

2.4.2. Hybrid cadastre:

Preservation of the 2D cadastre and integration of the registration of the situation in 3D by registering 3D situations integrated with 2D cadastral data. This result to a hybrid solution, where both 2D parcels and 3D registrations is included. As shown in Figure 2.11, the 3D representation can be either a volume to which a person is entitled [Alternative 1] or a physical object itself [Alternative 2].

The juridical and cadastral concept of ownership is not changed as in full 3D cadastre. RRRs are always registered on 2D parcels. The difference with existing 2D cadastres is the way RRRs are registered and visible in the cadastral registration.

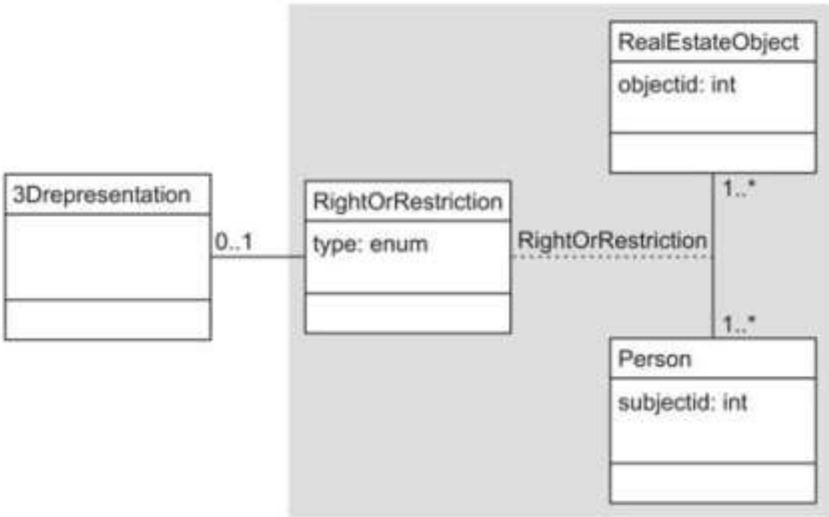


Figure 2.11: UML class diagram of the hybrid cadastre [Stoter, 2004].

- Alternative 1: registration of 2D parcels in all cases of real property registration and additional registration of 3D legal space in the case of 3D property units. It implies that the 3D registration of rights that are already registered and that are concerning 3D situations using 3D right-volumes. The parcel is the starting point of registration.
- Alternative 2: registration of 2D parcels in all cases of real property registration and additional registration of physical objects. The physical object is the starting point of the registration.

2.4.1. 3D tags linked to parcels in current cadastral registrations.

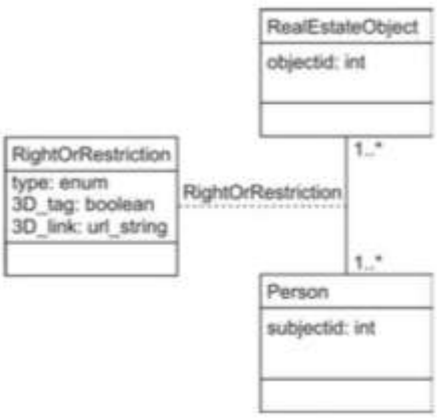


Figure 2.12:UML class diagram of 2D cadastre with 3D tags [Stoter, 2004]

As depicted in Figure 2.12, this concept means preservation of the 2D cadastre with external references to representation of 3D situations. It is the solution that requires the least fundamental changes of the current cadastral concept. This is due to the fact that real rights are always established and registered on 2D parcels. In addition to the '3D tag' on the parcel, a reference can be added to a legal document or to a drawing that illustrates the situation.

2.5. Different aspects of 3D Cadastres

3D cadastres have many different research aspects. The research trends in this area of cadastral research supports this: in their survey of topics in 3D property research over a ten year period from 2001 [see Figure 2.13 below], Paulsson and Paasch [2011] found that institutional topics (i.e. legal and organizational) accounted for only 30 per cent (31 instances of primary research) of all research. Of this, the research was almost overwhelmingly [just over 90 per cent] focused on legal aspects, with few instances of primary research being conducted on the organizational aspects in support of 3D cadastres.

Year	Legal	Technical	Registration	Organisational	Total/year
2001	6 (8)	8 (5)	11 (5)	1 (6)	26
2002	2 (1)	2 (2)	4 (3)	0 (1)	8
2003	2 (2)	1 (0)	2 (4)	1 (1)	6
2004	3 (3)	4 (4)	4 (4)	1 (1)	12
2005	0 (2)	4 (1)	5 (0)	0 (0)	9
2006	2 (1)	2 (1)	3 (2)	0 (0)	7
2007	1 (0)	1 (0)	0 (0)	0 (1)	2
2008	2 (0)	0 (1)	2 (0)	0 (3)	4
2009	2 (1)	3 (0)	2 (1)	0 (1)	7
2010	6 (4)	6 (2)	3 (2)	0 (2)	15
2011	2 (3)	5 (0)	2 (5)	0 (3)	9
Total	**28 (25)**	**36 (16)**	**38 (26)**	**3 (19)**	**105 (86)**

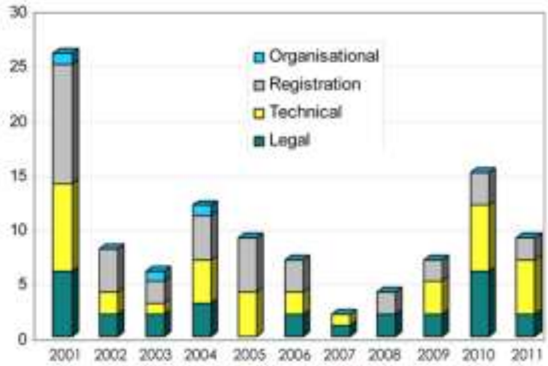


Figure 2.13: Distribution and break down of the surveyed 3D research publications and topic distributions [Paulsson & Paasch, 2011].

This means that a 3D Cadastre that best depicts the reality including all the special cases is regarded as a tool for development in the field of land management. In order to achieve that, the technical, legal and institutional aspects of each country should be harmonized and cooperate [see Figure 2.14].

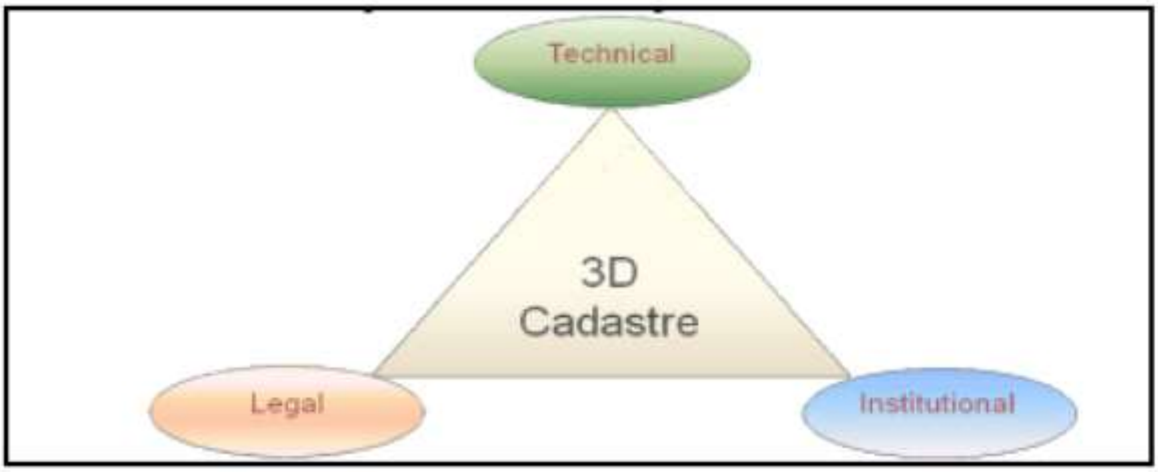


Figure 2.14: Basic aspects of 3D Cadastre that need to cooperate [Aien et al., 2011].

2.5.1. Legal aspects of 3D Cadastre

Legislation is a foundation of 3D property. Without proper legislation, 3D properties cannot be formed [Jenny et al., 2013]. Legislation is a significant issue of 3D cadastre and many researchers stress in this domain [Dimopoulou, 2013; Gerhard, 2013].

The literature supports the need for 3D property to be established administratively, i.e. provided with legal status and establishes its relationship with other RRRs. Inherent in the establishment of rights is the issue of registration and the instruments that support the ability to unambiguously define the extent of rights.

Therefore, the legislation framework of each country must support the geometric definition and location of these RRRs in a clear and consistent manner. This requires some prescription [legal or regulatory] to standardize methods for the definition of 3D property RRR boundaries and to locate its position relative to boundaries of other RRRs. The introduction of a vertical dimension is therefore logical and facilitates the definition, representation and relationship of RRRs in strata objects, i.e. "rights with 3D characteristics" [Van Oosterom et al., 2011, p.17].

In general, the legal issues found in the literature, mostly concerned the concept of 3D property [e.g. Stoter & Zevenbergen, 2001; Fendel, 2001; Stoter, 2004; Paulsson, 2007; Paulsson, 2008; Karki et al., 2010], as well as on how current legislative frameworks support autonomous registration of 3D property [e.g. Stoter & Zevenbergen, 2001; Huml, 2001].

There is international variance across what constitutes stratified RRRs, but Paulsson [2007, p.32] has defined the main types to be:

- independent 3D property,
- condominium [apartment ownership],
- indirect ownership and
- granted rights.

Those four categories reflect diversity in perspectives and land policies in different countries and cities towards ownership, boundary definition, property management and common property [Paulsson, 2012].

Moreover, in some countries there is no doubt that legal reform is required either for including the 3D property as a term and define ways to manage it, wither because 3D property already exists but cannot be established as a secure entity, either because the legislation framework does not cover future developments mostly due to legal ambiguity,

For instance, in Finland, where 3D property cannot be formed, the use of alternative methods of registration and RRRs definition circumvents this issue [Vitikainen and Hiironen, 2012]. Some other countries have already undergone recent reform to the legislation framework to support 3D property; which has been beneficial in providing greater clarity. For example, China introduced a new property law in 2007 to support 3D properties and associated rights and Hungary enacted legislative modifications in 2011 to current acts to ensure clarity on the legal establishment and definition of 3D property and associated rights [Iván, 2011].

However, very often it is unclear whether and if yes, what kind of reform is required. In order to overcome the limitations of 2D cadastral systems, many countries establish 3D properties by using existing juridical boundaries of the base 2D land parcel eg. the Netherlands and Australia [e.g. Stoter & Zevenbergen, 2001]. A recent comparative study by Dimopoulou and Elia [2012] looking at the function of land law in Greece and Cyprus relevant to RRRs also provides another potential situation where legislative reform lies in a grey area: in this instance, customary traditions that bestow 3D property rights are still practiced even though they contravene the civil code.

As more and more countries move towards developing prototype systems and implementing 3D cadastre pilots, it is becoming evident that legislative reform may not be as significant a factor for progress as once thought [Ho et al., 2013].

Addressing the primary issue of 3D property rights, current research shows that in many countries, legislation originally designed for managing 2D properties are flexible enough to accommodate 3D properties, as is the case in Sweden, The Netherlands, Queensland and Victoria [Paulsson, 2012; Stoter et al., 2012; Karki et al., 2013]. In addition, there can be little fundamental difference in the registration of 2D or 3D properties and their resulting legal status [Sandberg, 2001].

From all the above mentioned it is clear that the law can affect the legitimacy of 3D property in different ways, due to different reasons. The literature in this domain has mainly concentrated on issues best dichotomized as being addressed at the broad level of public or private law [Ho et al., 2013]. These include, but are not limited to:

- the concept of a 3D property, its legal status and classification of associated rights [e.g. Stoter & Zevenbergen, 2001; Fendel, 2001; Stoter, 2004; Paulsson, 2007; Paulsson, 2008; Karki et al., 2010];
- questions raised over the legislative framework required to support autonomous registration of 3D property [e.g. Stoter & Zevenbergen, 2001; Huml, 2001];
- jurisdictional legislative limits and considerations [e.g. Huml, 2001; Sandberg, 2001; Stoter & Ploeger, 2003; Papaefthymiou et al., 2004; Aien et al., 2011; Tan & Hussin, 2012];
- registration of real property vs. physical objects [e.g. Ossko, 2001];
- effect of public law on private rights [Navratil, 2012]; and
- common property regimes [Paulson, 2012].

Figure 2.15 shows a graphical representation of the legal issues of 3D cadastres and their inter-relationships.

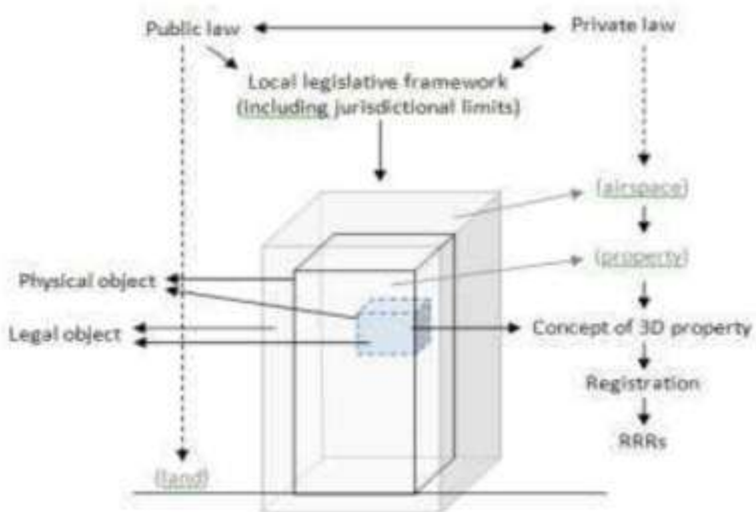


Figure 2.15: Physical representation of legal issues in 3D cadastres [Ho et al., 2013].

It became apparent that many jurisdictions all over the world found an alternate path forward either within the bounds of its legal framework or in spite of it, given the immediate need for 3D property registration for the continued functioning of land markets. This challenges the dominant assumption within the 3D cadastre research domain that attributes the lack of progress towards implementation as resting mainly on legal limitations.

Ho et al. [2013] introduced institutional theory and a theoretical institutional framework for the impact that legal issues have in the implementation of 3D cadastre. These were fundamental in reconceptualising the role that legislation plays, especially if considered as part of a broader landscape of institutional factors. Consequently, their research showed that the legal framework, regardless of its current level of support of 3D property registration, actually plays an enabling role in 3D cadastral implementation. This has less to do with the regulatory characteristics typically associated with the legislation, and more to do with understanding its broader social function as a means of shared sense making through the application of an institutional lens (with regards to new registration situations posed by complex 3D situations).

More international comparative legal research should be conducted [Paulsson, 2012], although doing so may be very difficult because of the differences in national terminology. The current informative Annexes F "Legal Profiles" and "Code Lists" of the ISO 19152, LADM and the Legal Cadastral Domain Model [LCDM] as developed by Paasch [2012], may be used as starting or reference points in international legal research and development.

2.5.2. Technical aspects of 3D Cadastres

Apart from the administrative and legal issues of the 3D Cadastres, the technical issues are very important and also challenging. The need to handle spatial data in the third dimension is growing and providing the spatial extend, DBMS and visualization environments have been challenged by the third dimension.

The generation of 3D cadastres should take into account existing communication protocols and standards for modeling, data storage and representation. Towards this direction, many prototypes, pilot programs and proposals for visualization have been conducted the last decade.

There have been huge amount of data that show what 3D objects look like but they usually consist of individual faces. Real geometric 3D body is required to describe the true 3D characteristics of the objects. According to Ying et al. [2011], at least three aspects should be clearly presented in order to manage the 3D parcels correctly:

1. The precise geometric model that describe the shape and geographic location of various 3D parcels, mainly based on sets of flat faces.
2. A solid model that indicates its entire boundary faces with orientation to present the corresponding 3D parcel object.
3. The topological relationships that encode the information about the adjacencies among the solids/parcels shared common faces to keep the consistence of the objects' geometries.

The same authors create a 3D topology based prototype of ISO 19152 LADM, where some topological queries and operations can be performed [see Figure 2.16].

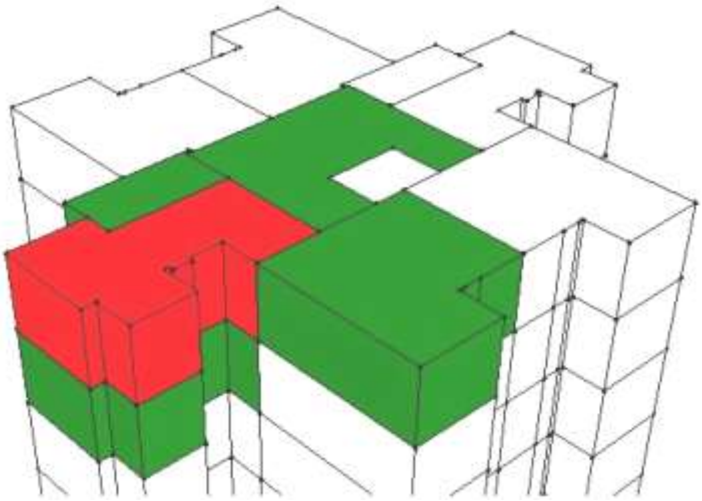


Figure 2.16: Topological query [Ying et al., 2011].

I. Data storage

DBMS have been traditionally used to handle large volumes of data and to ensure the logical consistency and integrity of it. Geospatial databases have been used for years in the geospatial industry and offer numerous advantages such as scalability, security and standardization. For years, spatial data used to be organized in dual architectures consisting of separated data management for administrative data in a Relational DBMS (RDBMS) and spatial data in a GIS. This approach usually results in inconsistencies; for instance, if the attributes of a record are deleted from the database, there is no check that the spatial component of this record will also be deleted from the GIS. A solution to that problem was to use a layered architecture, in which all data is maintained in a single RDBMS.

Presently, most DBMS offer spatial data types and spatial functions usually in an object-relational spatial extend to RDBMS [Zlatanova & Stoter, 2006]. Storing spatial data and performing spatial analysis can be completed with SQL queries. Integrated queries on both spatial and non-spatial parts of features can be executed at the database level. The spatial data types and spatial operations reflect only 2D objects, though embedded in 3D space. This support of 3D/4D coordinates allows for alternatives in management of 3D objects.

A number of experiments were performed by several researchers to investigate possibilities to store, query and visualize features with their 3D coordinates in mainstream DBMS; Oracle, PosrGIS, MySQL, IBM, Ingres and Informix [Arens et al., 2006; Stoter & Zlatanova 2003; Pu, 2005; Zlatanova et al., 2002; Zlatanova et al., 2004]. Zlatanova [2002] summarizes the conclusions of those experiments into two categories; good and bad news. The good new is that 3D data can be organized in DBMS, retrieved and rendered by front-end applications. However, there since no 3D data type is currently supported by any DBMS, the user remains self-responsible for the validation of the objects and for implementing true 3D functionality.

In particular, all the above-mentioned DBMSs offer 2D data types (basically points, lines and polygons) and also support 3D/4D coordinates (except Ingres, which is 2D) and offer a large number of spatial functions usually compliant with the OGC standards. Most of the functions are only 2D, apart from PostGIS, which supports 3D spatial operations.

Two types of models have been examined in many studies across the literature: topological and geometrical. Topology is one of the mechanisms to describe relationships between spatial objects and it is the basis for many spatial operations. The geometrical models are easier to implement. Several DBMSs, such as Oracle, IBM, Ingres and DB2, support spatial objects organized in geometrical models. Some of them even follow the Open GIS standards.

In addition, many GIS and CAD packages, such as MapInfo, ArcGIS and AutoCAD use geometrical models of DBMS [Zlatanova et al., 2002]. 'Real' and 'complete' 3D objects and their corresponding functions cannot be implemented today by most of the geometric types supported by DBMS. Usually, 3D spatial objects can be displayed as 2D objects with 3D coordinates, but the spatial operations are limited to 2D [Zlatanova et al., 2004].

A number of topological models for 2D and 2.5D spatial objects have been implemented, or are under consideration by GIS and DBMS vendors. Compared to geometrical models, the development of topological models is much more complex into the 3D dimension. 3D topology is still being researched as the third dimension introduces many issues in representing the objects and their relationships. Also, the suitability of topological models in 3D for different applications varies, as there is not one 3D topological model that is suitable for all types of applications. According to Zlatanova et al. [2004], there are two main groups of data structure found in the literature: those that maintain objects (OO – object-oriented) and those that maintain relationships (topology-oriented).

The most discussed 3D objects that are supported in the DBMS mentioned before are usually volumetric objects. The data types that can be used from the user to manage them in a database are *polygon* and *multipolygon* or creating a *used-defined data type*. For a simple volumetric object, *polyhedron* [consisting of arbitrary number of planar polygons which have arbitrary number of points], *triangulated polyhedron* [consisting of arbitrary number of triangles] and *tetrahedron* [consisting of four triangles] can be easily realized with provided data types. Each one of them has its own advantages and disadvantages and the selection depends on the end product. Apart from them, 3D line objects are used to represent utility networks [lines with 3D coordinates] using the supported spatial data types *line* or *multiline*.

Additionally, 3D point objects, which are massively used the last years due to the advances of sensor technology, which produce large amount of specific 3D point data [point clouds] are included into the DBMS. They can be organized either by using the supported spatial data types *point* [Figure 2.17] and *multipoint* or creating a *user-defined type*.

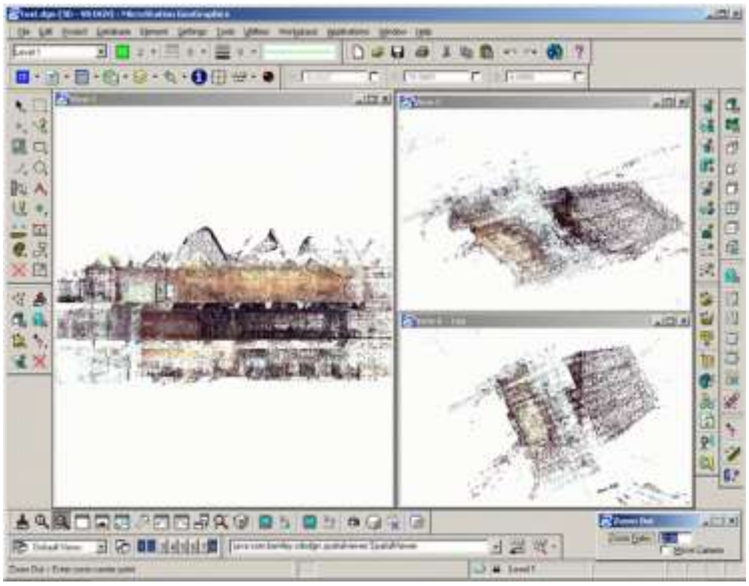


Figure 2.17: 3D visualization of point clouds, managed as points in DBMS [Zlatanova, 2004].

Last but not least, freeform curves and surfaces such as NURBS, B-spline and Bezier, are becoming progressively important for modeling 3D objects [Figure 2.18].

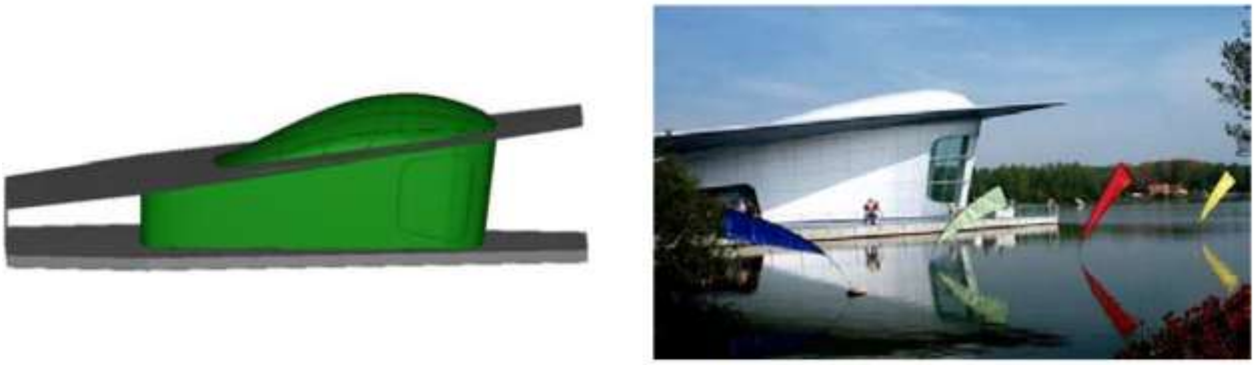


Figure 2.18: NURBS building retrieved from DBMS [Zlatanova, 2004].

A 3D cadastre system is not only about managing 3D property features with geometry and attributes. Many other documents, such as legal documents, urban plans, as well as scanned deeds and plans, are all part of the cadastral record and require efficient management processes. These documents are in different forms such as PDF, doc, txt, and tiff files, and are frequently managed with content management systems. One major benefit of managing these heterogeneous documents is the ability to integrate them with geospatial data. This can be achieved by associating spatial locations with these documents. Therefore, documents can be represented on a map and found through a spatial query.

Another way to integrate images and documents is to link them to existing spatial objects such as a cadastral parcel. Figure 2.19 shows documents managed within Bentley Geospatial Server consisting of a tree-viewer, which supports navigation through the data and an interface showing the representation a 2D representation of the data [top view of a 3D model] [A Bentley White paper, 2011].

Figure 2.19: Managing different documents using Bentley Geospatial Server [A Bentley White paper, 2011]

II. Visualization

Visualization issues in the context of implementing 3D Cadastre systems was one important outcome identified at the 1st 3D Cadastre workshop [Fendel, 2001].

During the last decade a number of research activities in the field of 3D cadastral visualization have been reported and various prototype systems have been developed [Frédéricque et al., 2011; Hassan & Rahman, 2010; Jarroush & Even-Tzur, 2004; Stoter & Zlatanova, 2003]. A general architecture for 3D cadastral visualization systems is presented in Diagram 2.3.

The current status of visualization in 3D cadastre was addressed by Pouliot [2011] and important issues and problem such as preconditions for data visualization, new realities which influence 3D visualization, purposes of visualization, users, and technical problems were discussed and some solutions proposed [Shojaei et al., 2013]. At that time, no specific recommendations were made about the requirements needed for the visualization of 3D parcels. Notwithstanding this research and progress, there is no fully operational digital 3D cadastre in the world and existing functionality is limited to basic activities such as registering volumetric parcels [Van Oosterom et al., 2011]. Throughout the time, it was realized that data visualization requires the combination of a large variety of domains all converging to communicate a comprehensive and coherent message to human.

MacEachren et al. [1992] defines Geo-visualization as "*… the use of concrete visual representations… to make spatial contexts and problems visible, so as to engage the most powerful human information-processing abilities, those associated with vision*". For this field, the geometry [location, form, size and orientation] and/or spatial distribution [patterns, trends and correlation] of geographic characterizes are the most important aspects that should be described.

Various categories of geotechnologies exist such as Geographic Information System [GIS], spatial database management system [S-DBMS], Computer Aided Design [CAD], computer graphics, virtual reality, video games, web-based browsers [based on 3D Globes or not], mobile device [e.g. smartphone], or even simple viewer such Adobe Acrobat Reader [3D PDF]. Some progresses in GIS and S-DBMS have been made for 3D geovisualization. For instance, GIS now supports various categories of 3D spatial representations, manages levels of details [LoD] models or proposes enhanced import/export capabilities. CAD software already offers powerful capabilities for 3D visualization but they are currently improving the management of georeferenced and descriptive data, the integration of spatial standards and the on-the-fly creation of solids from faces [Pouliot, 2011].

In addition, Internet and Web offer today several options for 3D geovisualization. The beginning was made by the use of 3D globes, such as Google Earth and Bing Map, which contributed to the democratization of spatial data to a huge public. The development of Web browser usually requires user to install a plug-in, to provide better performance. HTML5 [by W3C], has already become a dominant technology on 3D visualization in browser. This is also related to *mashups*, solutions that integrate the concepts of tagged geographical data and API in order to enable the superposition of various sources of geospatial data.

Pouliot [2011] refers to the most important reasons that we need development on the field of geovisualization, the technical problems that exist, the interoperable standards that should be used and also to the technologies that have been developed. At the moment, all those problems and challenges are taken under consideration and the geovisualization in is in early steps with pilot and prototype projects that try to represent the 3D aspects of the real property. Some applications and/or pilot programs were designed o demonstrate the feasibility and advantages of using 3D geo-visualization software for cadastre data, mainly focusing on the technical aspect, examining the possibilities of current technology [De Vries & Zlatanova, 2004; Miguel et al., 2011; Aditya et al., 2011].

On the other side, according to the graphical semiology of Bertin [1983], the cartographical foundations of the visualization and the visual variables should be studied. Until today, there is not so much literature in this topic. A preliminary experiment was conducted in 2012 by Wang et al., aiming to investigate which among the visual variables are more appropriate for geo-visualization of 3D legal units in 3D Cadastres: position, size, color, orientation, shape, value and texture.

One year later, Pouliot et al. [2013], conducted a second experiment about the semiology o 3D Cadastres, with notaries in the form of face-to-face interviews. The last experiment conducted in 2014 by the same authors [Pouliot et al., 2014], based on the hypotheses "Transparency is performing to distinguish two groups of bounding objects such as physical and legal and to give the impression of ownership". Some preliminary results have been published, but additional results and data analysis are needed to get more investigation.

A general architecture for visualization has been proposed by Shoiaei et al., 2013 as depicted in Diagram 2.3.

Elizarova et al. [2012], conducted one of the most complete pilot programs in this domain; where 3D cadastre model for the Russian environment was created based on the ISO 19152 LADM and a prototype was developed based on that model. In addition, a data preparation process for 3D cadastre on pilot was developed and the prototype was tested in conditions of a pilot region.

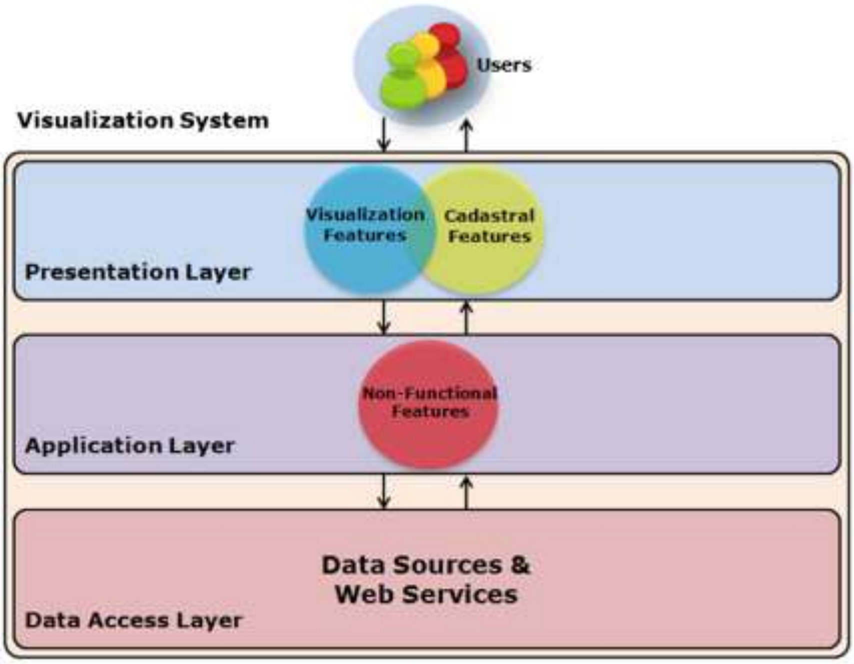


Diagram 2.3: A general architecture for visualisation in 3D Cadastres [Shojaei et al., 2013].

The option of a polyhedral legal 3D cadastre based on the representation of 3D objects as polyhedrons [volumes limited by flat faces] was selected as a working model. For technical implementation, a solution involving the existing 2D portal and linking it with a new 3D-Viewer was selected. It could display both the 3D objects and the legal cadastral information of these objects. The result was a Web-based interface, which can interact and query 3D cadastral objects, as shown in Figure 2.20.

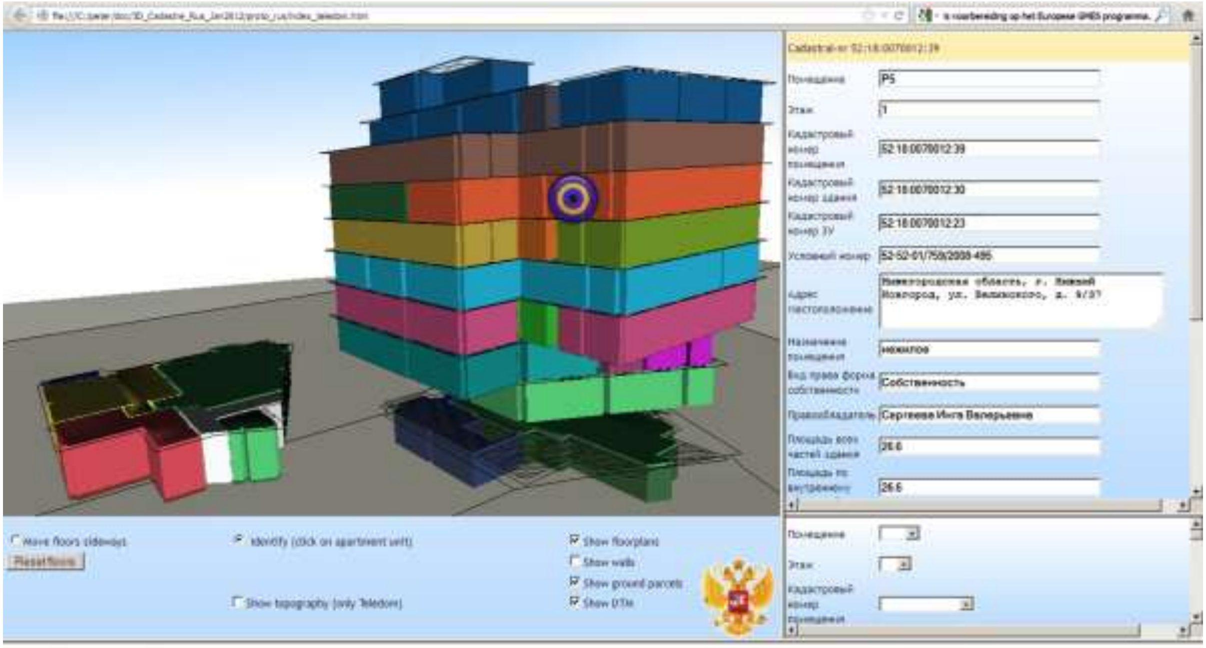


Figure 2.20: Interacting with 3D parcels - Floor 01 dragged outside of the buildings [Elizarova et al., 2012]

The visualization and/or interaction with 3D cadastral parcels require more attention and may be quite different from the more 'experienced' visualization of 3D city models.

According to Wang et al. [2012] the most specific key points when visualizing 3D cadastral parcels are as follows:

- How to visualize dense 3D volumetric partitions such as in a complex building because the first visible outside layer of 3D spatial units blocks a view of the others—solutions could be based on selections and the use wireframes and semi-transparent objects, showing cross-sections/slices, or applying slide-out layer techniques as developed in the Russian prototype; see Figure 2.20.
- How to display open or unbounded parcels,
- How to include the earth's surface and/or other reference objects [e.g., CityGML-like[for 3D cadastral parcels,
- How to provide the proper depth cues for subsurface legal spaces related to utilities [e.g., use stereo, perspective, movement/rotation, or connecting vertical sticks from a subsurface object to the earth's surface].

Another option was introduced by Aditya et al. [2011], who presented a 3D cadastre web solution in order to support data management and visualization. They concluded that a seamless integration between web database and 3D visualization components that are available in the market is not possible yet.

The same authors emphasize the use of open source standards to facilitate data integration and visualization. For instance, KML format is capable to be used as an intermediate format for converting CAD data into spatial database. Regardless the limitation of the existing geo DBMS in storing 3D geometries, the presented solution, that proposes the use of KML and PostGIS, is considered to be sufficient to extend 2D cadastre geodatabase into 3D hybrid cadastre geodatabase. In this respect, hybrid cadastre refers to a solution that integrates 2D geometries of land parcels and 3D geometries of the property units [Stoter & Van Oosterom, 2004].

The use X3D format to present 3D objects with its associated attributes has a promising future to present 3D cadastre data. As presented in Figure 2.21, terrain and buildings can be integrated and then be related to their corresponding attributes for web visualization [with X3D plug-in] using e.g. AJAX application framework.

Further development is needed in order to make X3D as a GIS-ready platform to visualize and also analyze geospatial features via the Internet. Some constraints that need to be improved include inconsistent visualization of 3D objects and terrain data between one 3D graphics browser to other browser.

Current open source software development and computer graphics technologies can be considered far from sufficient in enabling optimal online 3D data sharing and visualization. Challenges include insufficient support for spatial data types in spatial databases, immature 3D representation and data modeling of 3D space, inconsistent 3D representation detail and accuracy across 3D browsers.

From the conclusions of this research, it can be stated that X3D format still has difficulties in dealing with parcels [especially those constructed from polylines] and 3D surfaces. Thus, 3D visualization options using open source 3D formats and browsers are still limited.

As a consequence, the texture mapping of images into terrain surfaces or into 3D objects was considered not succeeded in this project. In contrary, tightly coupled 3D modeling and visualization using ArcGIS or Bentley Microstation [Frédéricque et al., 2011] software package provides high-quality 3D visualization results but it requires more hardware resources than using open source format and 3D browsers. Additionally, possibilities for full data interoperability are limited.

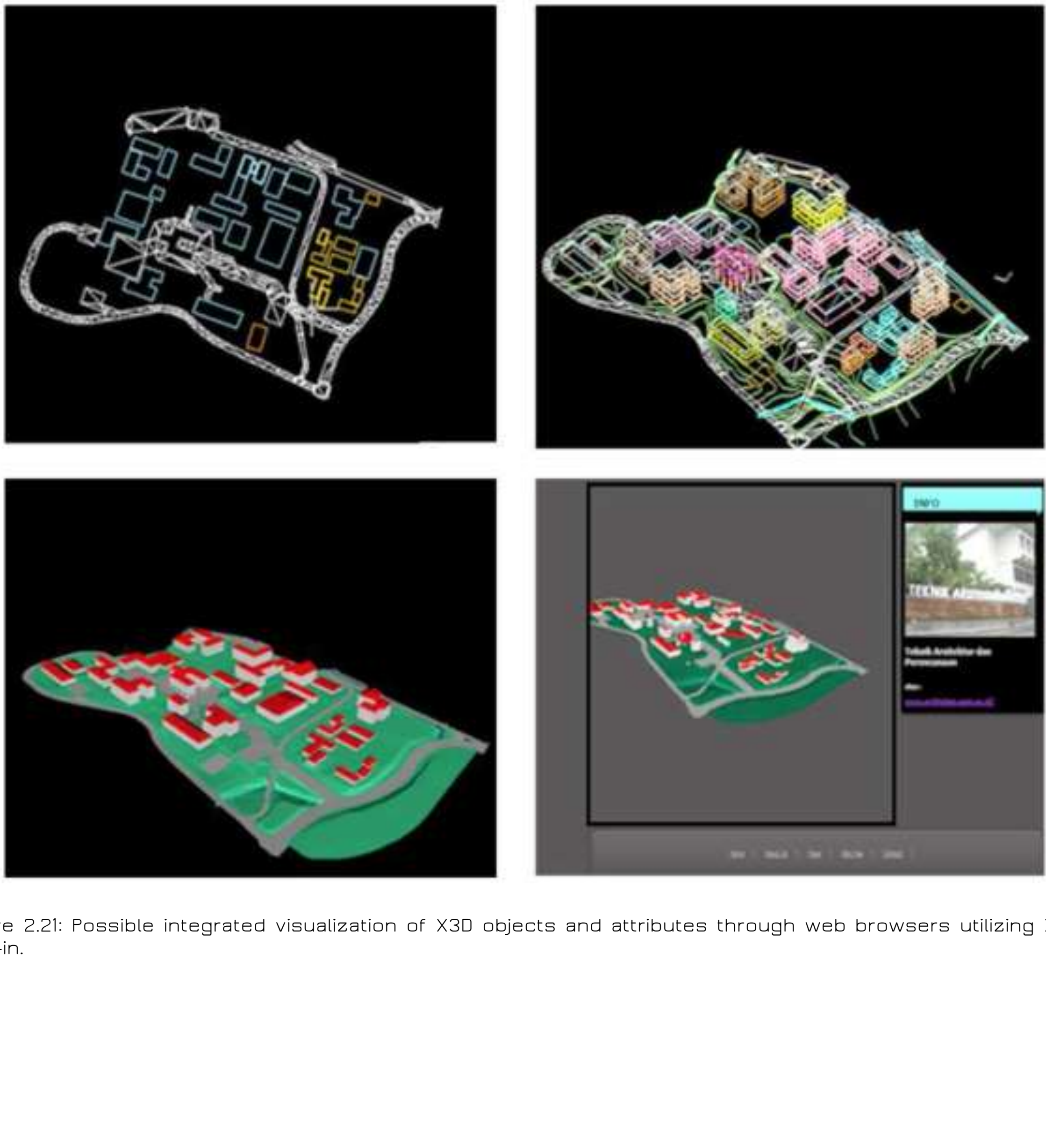


Figure 2.21: Possible integrated visualization of X3D objects and attributes through web browsers utilizing X3D plug-in.

A recent developed prototype for Shenzen, China, is one of the most coherent and complete programs developed to meet the requirements of 3D land use. At first, the 3D cadastral system in China was focused in academic research, including geometry of 3D objects, compatible 3D data models, generating 3D model data and 3D topologies [Guo et al., 2013]. After two years' developments, the focus moves towards the implementation and forms a special model for 3D cadastral administration.

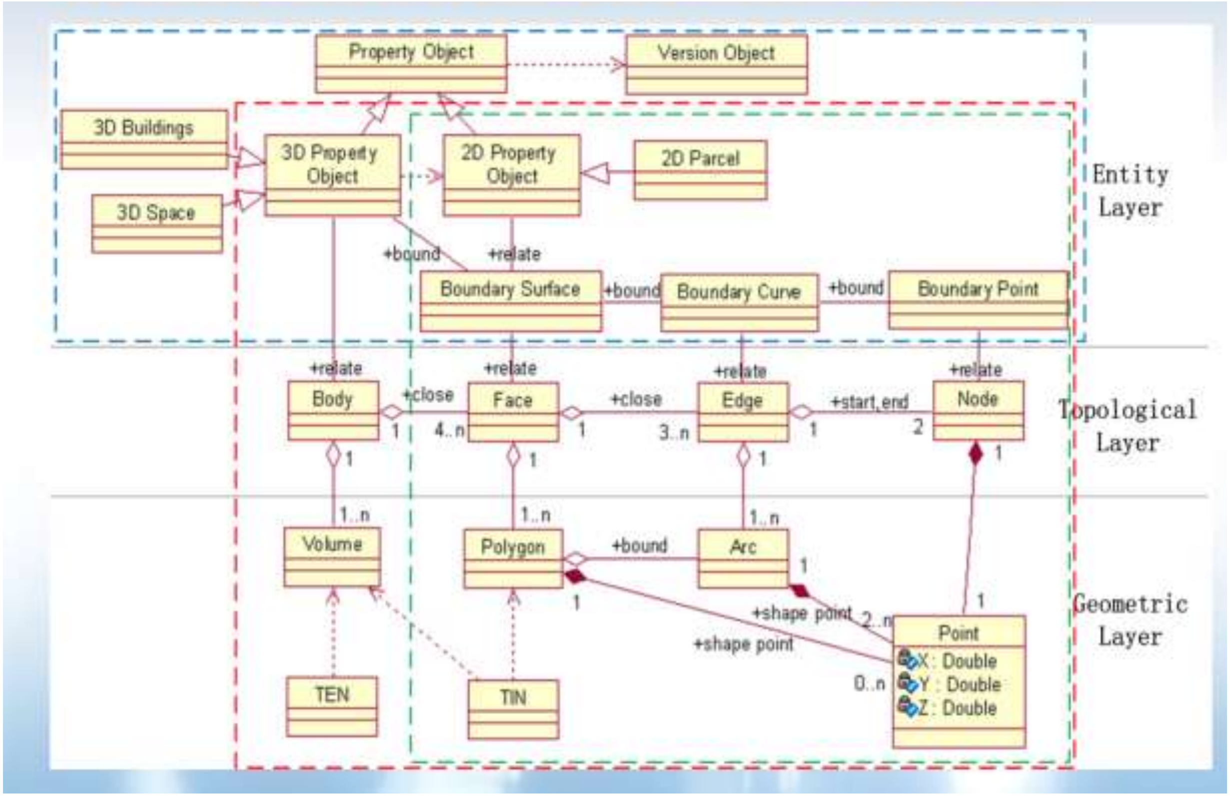


Figure 2.22: Detailed design of 3D spatial data model.

At the 3D spatial data model [see Figure 2.22], there exist three layers, the geometrics, the topological and the entity layer. In the geometric layer the basic primitives for constructing 3D solids are the geometric primitives; point, arc, polygon, TIN, TEN and volume. In the topological layer, the primitives for constructing 3D solids are topological primitives [node, edge, face and body] composed of geometric primitives.

In the entity layer, cadastral entities [boundary surfaces, boundary curves and boundary points], which form property objects could also be, regarded as topological primitives combined with semantic information [Guo et al., 2012].

Moreover, a 3D cadastral database was created including the spatial database, the attribute database and the historical database, where both 2D and 3D data are stored. In addition, a data-generating module is a significant module as it creates 3D spatial data with different ways, including both regular data [those which can be generated by extrusion] and irregular [solids which have concaves or holes].

Moreover, the 3D query platform and 2D platform are in a unified framework, which allow the visualization of a 3D scene, as depicted in Figure 2.23 and Figure 2.24.

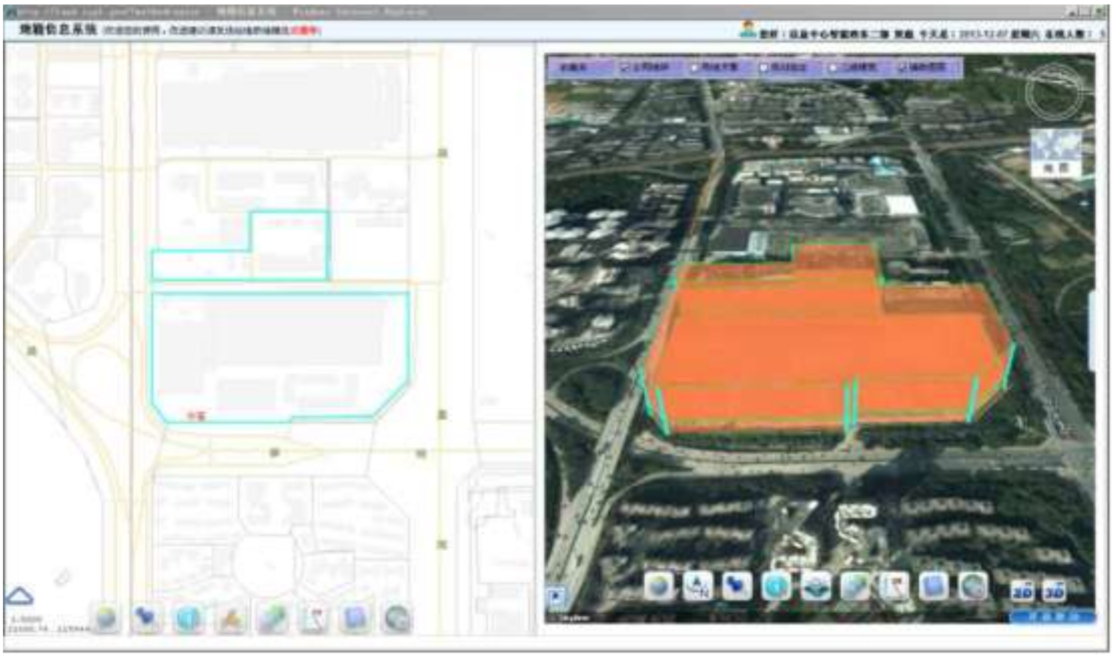


Figure 2.23: The interface od 3D and 2D platform [Guo et al., 2013].

Figure 2.24:Query in 3D scene [Guo et al., 2013].

2.6. nD Modeling of Spatial Information

Cities, and in general the urban environment, are dynamic living organisms in which the geographical information plays dominant role. The availability of spatio-temporal databases nowadays facilitate and enhance the use of geo-information in many applications, also in the domain of land management.

Undoubtedly, 3D geo-information has become a significant research field due to the increased complexity of tasks in many applications [Lee & Zlatanova, 2009]. The existing technological developments (spatial databases able to hanfle huge amount of data, ISO standards for geo-information, data exchange formats, visualization environments for multiple directions, introduction of semantics in order to reduce complexity, etc) enable the registration and manipulation of more than 2 dimensions, regarding the spatial data. It is evident that a complete model consists also of non-spatial attributes which are even stored at the same database with the spatial or in different databases and their communication is enabled usually with unique identifiers.

0D to 3D geometrical and topological characteristics of geo-data are the fundamental characteristics of the existing geographic information around the world. However, geo-information also has temporal aspects (e.g. when was an object valid in the database?) as well as scale components that were often implicitly taken into account when the data was collected.

The different dimensional aspects highly correspond, e.g. a (possibly geometric) change may be only relevant for the highest scale of an object or understanding the route directions for a long car trip requires overview, but at specific locations consistent information at a higher scale, with also temporal information may be needed. Although scale is a well-known concept in the geo-information technology domain, regarding it as an extra dimension of geodata, integrated with the other dimensions, is new [Van Oosterom & Stoter, 2012].

Until now different dimensions of geo-information have been studied in multiple initiatives, with sometimes limited support for the other dimensions. Although past research offers important knowledge on how to handle the 2D/3D dimensions, the time and the scale, individually, there is no modeling approach which truly integrates all those dimensional concepts.

This was the driving force for Van Oosterom and Stoter (2012), who started a new research on a conceptual full partition of 3Dspace&time&scale (i.e. without overlaps and gaps) realizing it in a true 5D generic model. The methodology followed for this approach is presented in diagram 2.4. This true 5D approach provides a solid foundation for the GII for three core reasons:

- **The deep integration of all dimensional concepts** accomplishes a highly formal definition of geo-data (with 5D data types and 5D topological primitives). The associations between space, time and scale are fully addressed and no special cases need to be treated in another way.
- **The model enforces consistency** crossing dimensional borders, which improves the quality of geo-data.
- **Optimal efficient 5D searching and maintenance** can only be realized if a 5D data types and index/clustering is used. Otherwise the queries on the will first select space, then time and then scale (or in another order).

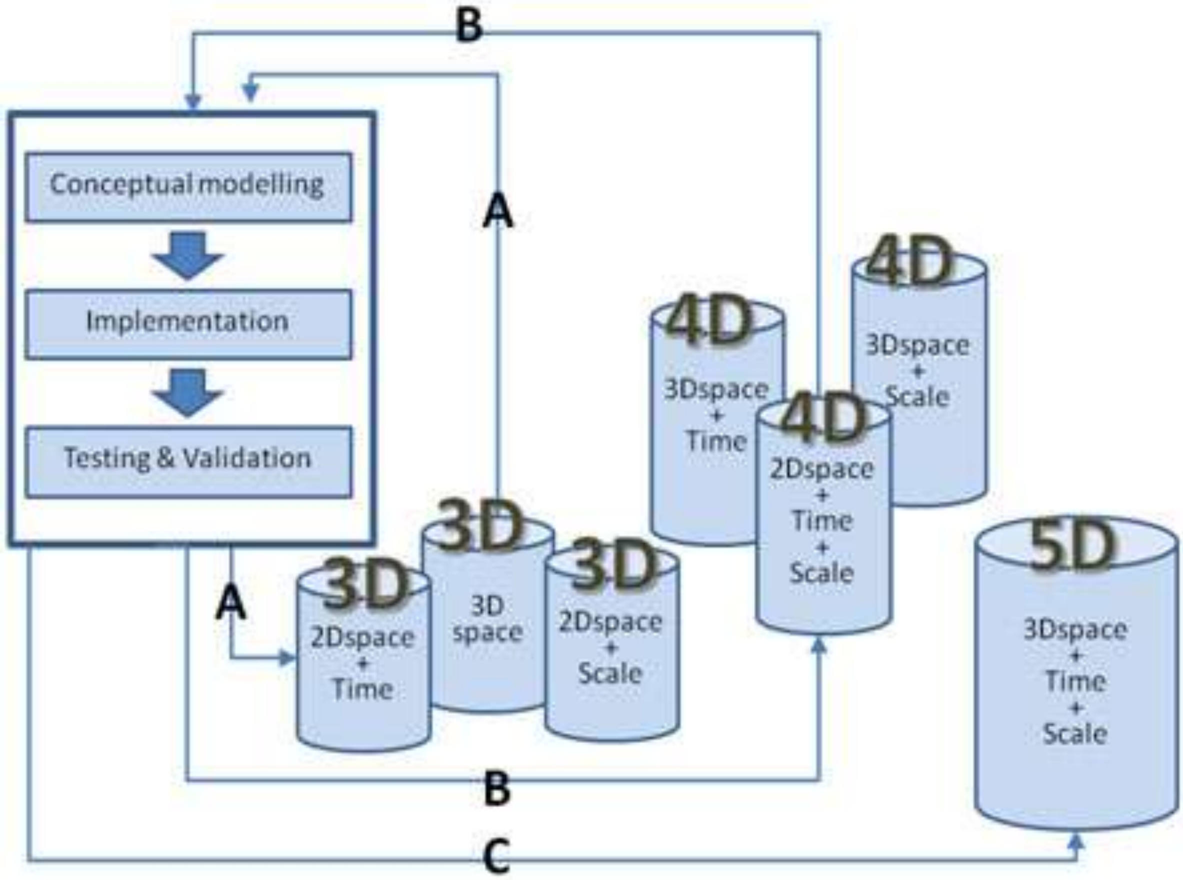


Diagram 2.4: Workflow of research methodology for 5D modeling [Van Oosterom & Stoter, 2012].

Modeling different scales of geo-data is related to the "*coarse-to-fine*" hierarchical structure of how we perceive, model and understand our environment. In some applications less detailed, but simpler data works better, especially when there is a need for an overview. In other cases very detailed data is required.

2.7. Conclusions

To sum up, a 3D cadastre will assist in managing the effects of 3D development and increase the functionality of a multipurpose cadastre [Stoter & Oosterom, 2006]. It is important to realize that a 3D cadastre solution always depends on the local situation and is driven by user needs, land market requirements, the legal framework, and technical possibilities and there in no single best solution for a 3D cadastre. There are several questions that need to be answered for each country in order to investigate the special needs for 3D cadastre, according to Van Oosterom [2013].

For instance, are the types of 3D cadastral objects that need to be registered, related to real-world objects (buildings, utilities, or other constructions) or not (airspace of arbitrary subsurface parts).

If related to real-world objects, how can the relationship between the 3D cadastral registration [legal spaces] and the registration of real-world objects be maintained within the context of the geo-information infrastructure (GII).

Nowadays more and more countries are moving towards the concept of a 3D cadastre. After past research and prototype developments, a new era has arrived with the first implementations and pilot programs of the first 3D cadastral systems in operation. It helps in communication to use existing standards when available [such as LADM] and to further discuss terminology and concepts [Van Oosterom, 2012].

As discussed previously, there are many 3D visualization systems for representing data in 3D, some researchers propose using CAD systems, other propose the use of GIS systems integrated with databases. However, these systems are still at a prototype level and require validation by users before being used in real applications [Pouliot, 2011]. Moreover, much work still need to be done for the definition of 3D RRRs, their storage and representation.

Additionally, temporal aspects of geo-data is fundamental for recording or monitoring changes, for describing processes, and for documenting future plans. Recent researches have introduced 5D modeling, including the time and the scale as fundamental aspects of the geoinformation. The multidimensional modeling depends on the final result and also the available data and technology. In some applications less detailed, but simpler data works better, especially when there is a need for an overview. In other cases very detailed data is required.

Figure 2.25: Vario-scaled: additional dimension [2D->3D] for topographic data [Van Oosterom, 2014]

3. Standardization

Until today most countries (states or provinces) have developed their own LAS. Some countries operate a deed registration, while others operate a title registration. However, different implementations of LASs do not make meaningful communication very easy, e.g. in an international context such as within Europe or in a national context where it may happen that different partners in development co-operation design and provide different LASs without co-ordination. Standardization is supportive and helpful in design and further development of LASs.

After the development of domain-independent standards for spatial and temporal schemas for spatial features [including metadata standards], a next step is the standardization of domain-specific standardized models, as a basis for standardized (Spatial) Information Infrastructures, also known as the Geoweb – development. Examples include International Standards for land cover [ISO 19144-2], Addressing [ISO 19160], Land Administration [LADM, ISO 19152], all within ICO/TC211. In addition, from OGC CityGML, GeoSciML, both based on GML3 are introduced and have a broader scope. Furthermore, at the European level, the INSPIRE directive has identified 34 different geo-information themes which should be harmonized.

It is relevant to keep data and process models separated; this means that [inter-organizational] processes can be changed independent from the data sets to be maintained. The data model can be designed in such a way that transparency can be supported: this implies inclusion of source documents and inclusion of the names of persons with roles and responsibilities in the maintenance processes into the data model. The number of attributes should be minimal; during the design of the data model there may be lack of awareness that there is something like a "multiplier": depending on the number of objects and subjects each attribute can have millions of instances [Lemmen & Van Oosterom, 2013].

Standardization is a well-known subject since the establishment of LASs. It concerns identification of parcels, documents, persons, control points and many other issues. It also concerns the organization of tables in the registration and references from those tables to other components, e.g. source documents and maps. Coding and abbreviations; e.g. for administrative areas; workflows, definitions etc. are all part of the standardization process both for paper based and for digital LASs [Lemmen, 2012].

But what can go wrong if you don't have standards?

Many things went well before standards were introduced. Greenway [2005] gives some examples of standards: the format of telephone and banking cards; the number of businesses implementing ISO 90003 [quality management] and ISO 14000 (environmental management); ISO codes for country names and languages and so on. He states that this list points to the ubiquity of standards, but also begins to indicate the economic benefits that they provide. That is the confidence that things will work and will fit together. He quotes key findings from a NASA5 report [NASA, 2005]: "Standards lower transaction costs for sharing geospatial data when semantic agreement can be reached between the parties", and "Standards lower transaction costs for sharing geospatial information when interfaces are standardized and can facilitate machine-to-machine exchange".

So, standards are, amongst other things, widely used because of efficiency and because of support in communications based on common terminology. One more issue is the LAS development on which many countries are working [Lemmen & Van Oosterom, 2013].

FIG stated the importance of the Cadastre from an international perspective for social and economic development [FIG, 1995]: the development of such systems should be promoted internationally, with attention to the needs and demands of societies with customary and informal tenures. The different needs of each country are underlined and is agreed that the framework can support plethora of legal, technical, administrative and institutional options of a cadastral system; providing the record a continuum of land rights, from private to individual rights [Lemmen, 2012].

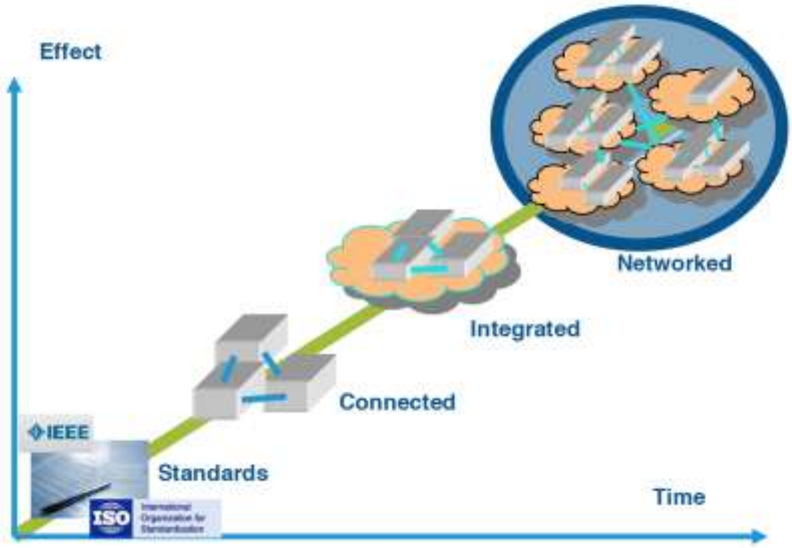


Figure 3.1:Land Administration Maturity Model [Van Oosterom et al., 2009]

Van Oosterom et al. [2009], based on Nolan [1979] show how standardization is contributing to the fact that LA is considered more and more the cornerstone of the information infrastructure combined both spatial and non-spatial registrations. As depicted in Figure 3.1, a model is used to specify four different levels of maturity: standards, connected, integrated and networked. Every step gives higher value and efficiency and can be met after finishing the previous one.

3.1.1. Object - Right - Subject Model

Henssen [1995] visualized the Object - Right - Subject relation in the model shown in Figure 3.2.

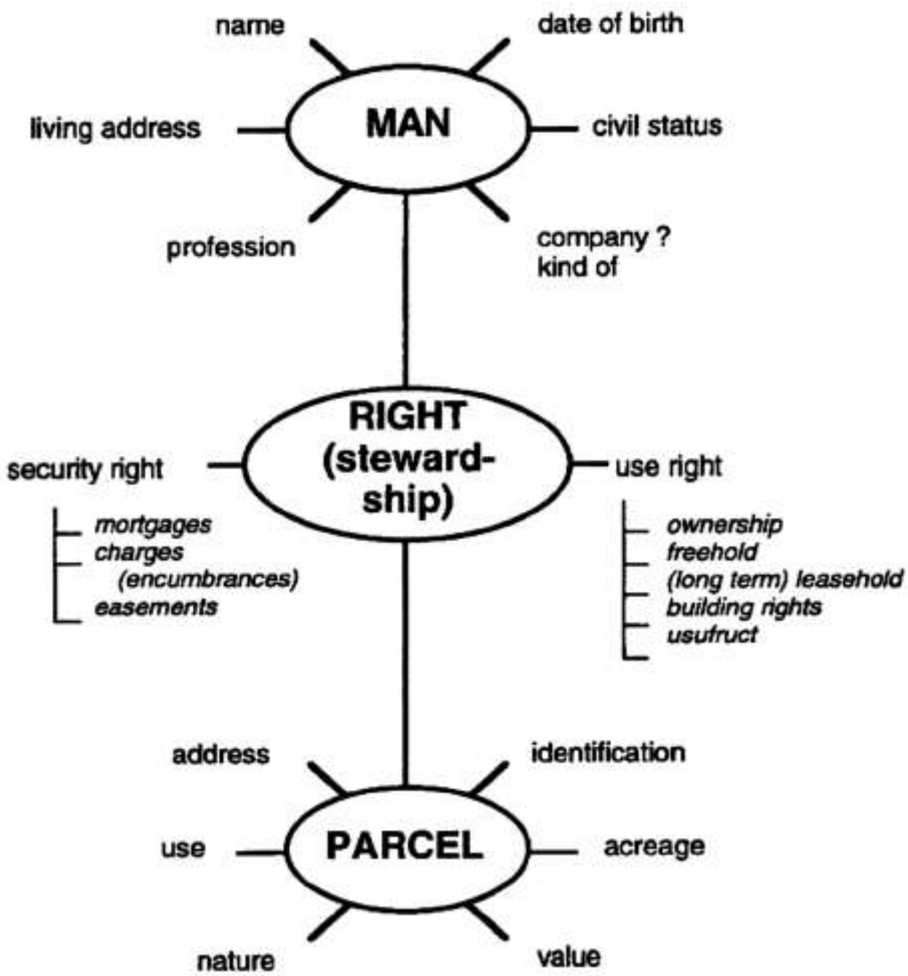


Figure 3.2 : The triple "Object - Right - Subject" [Henssen, 1995].

Henssen explained with this model that land registration and cadastre usually complement each other, and that land registration focuses more on the relationship *subject - right*, whereas cadastre on the relationship *object - right*. Kaufmann and Steudler [1998] recognise the structure from Henssen [1995] and make clear the difference between a deed and a title system. The deed system is *"man-related"*, as a deed becomes legally effective when it is registered in the official land register in relation to the rightful person.

On the other hand, the title system is *"land-related"* as the title is registered together with the indications about the rightful person in relation to the land objects [Figure 3.3].

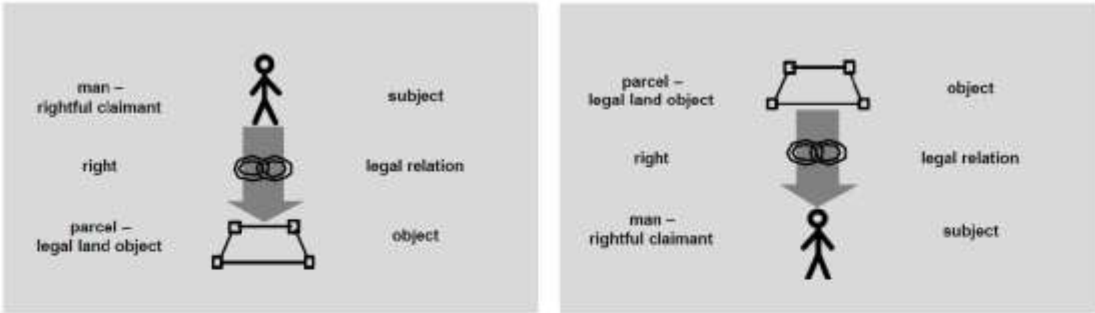


Figure 3.3: Left: relation "man-land" in deed system. Right: Relation "man-land" in title system [Kaufmann & Steudler, 1998].

In Van der Molen [2003a], it is argued that when it is assumed that the world's community is sincerely of the opinion that appropriate LASs are required for the eradication of poverty, sustainable development and economic development then it will be evident that attention should be devoted primarily to LASs of developing countries.

Therefore, in these countries it will be necessary to adopt new concepts in the design of LASs in order to take more into account the dynamism of land tenure, the land market, and government intervention in private property rights. Traditional basic concepts [objects, subjects, and rights[are already affected in three ways with regard to:

- objects: spatial units other than accurate and established units;
- subjects: group ownership with non-defined membership;
- rights: the recognition of types of non-formal and informal rights.

These new insights can be incorporated in a modification of the Henssen diagram presented in Figure 3.2 of the three basic concepts of LASs. The modified diagram is shown in Figure 3.4:

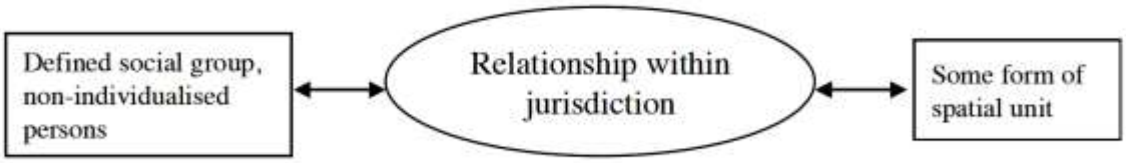


Figure 3.4: Modification of the Henssen diagram [Van der Molen, 2003a].

The same author adds some remarks regarding groups and individual group members; the entity exercising the land rights is now defined as a community. However, the individual members of that group are not specified and their rights pertain to a relationship with the land that is in accoedance with the needs and standards of the relevant community.

The object-right-subject model should be extendable to social tenure relationships: customary and informal rights [Lemmen, 2012].

The work of Kalantari [2008a], was based on the fact that LA with its existing digital systems is not flexible enough to accomondate new land related to interests as well as to respond to the increasing need of land information. According to him, LASs are not flexible for two reasons:

- parcel based indexing of interests in land cannot accomondate interests that are not necessarily equivalent to the extent ofland parcels.

- the maintenance of ICT systems based on LASs is complex and expensive. Interoperability is an important issue that should be considered when enabling future LA by ICT.

Kalantari proposes to replace the data model baesd on the physial land parcel by a spatially-referenced data model based on the legal property object, where every interest is uniquely combined with its spatial extent [see Figure 3.5].

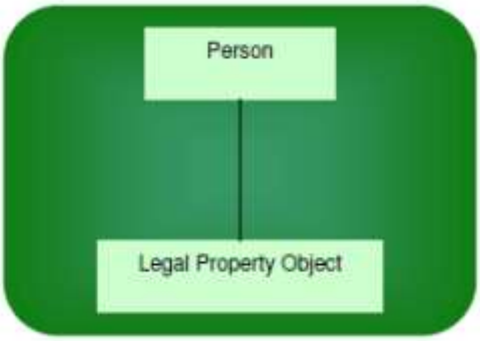


Figure 3.5: The legal property object model [Kalantari, 2008a].

Consequently, the relation between interest and its spatial dimension is that they together are a unique entity in the real world [Lemmen, 2012].

3.1.2. The Continuum of Land Rights

It is recognized worldwide, that the legal frameworks as used in developed countries do not serve the millions of people whose tenures are predominantly social rather than legal. This relates to the Continuum of Land Rights [Figure 3.6[where the range of possible forms of tenure is considered as a continuum. Each continuum provides different sets of rights and degrees of security and responsibility and enables different degrees of enforcement [UN-HABITAT, GLTN 2008].

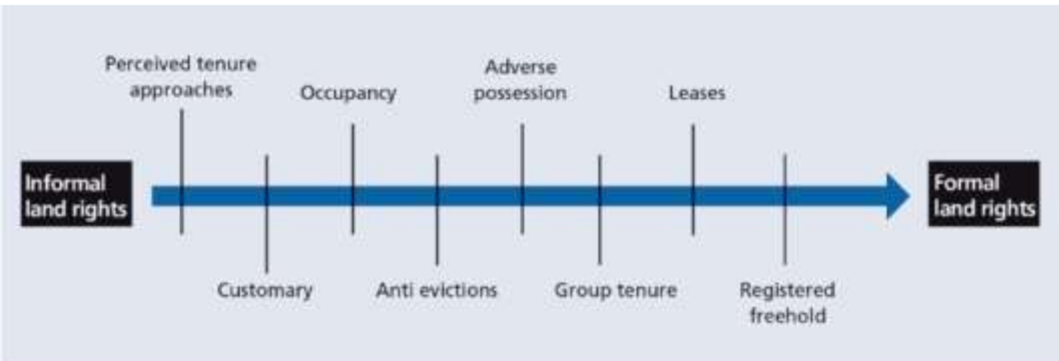


Figure 3.6: The continuum of land rights [UN-HABUTAT, GLTN 2008].

The development of LADM is based on user needs; comprehensive overview of requirements for the Land Administration Domain is available in [Lemmen, 2012]. Open markets and globalisation require a shared ontology allowing enabling communication between involved persons within one country and between different countries. One of the LADM requirements is the Continuum of land rights and the impact is described below:

The Triple Object [Spatial Unit] - Right [RRR] - Subject [Party] is the common pattern for Land Administration and is the basic structure [Lemmen, 2012;

Lemmen & Van Oosterom, 2013]. Groupings of objects or subjects should be supported. The flexibility of the model should be based on the recognition that people's land relationships appear in many different ways, depending on local tradition, culture, religion and behaviour.

It should be possible to merge formal and informal tenure systems in one environment. Land rights may be formal ownership, apartment right, usufruct, freehold, leasehold, or state land. It may be social tenure relationships like occupation, tenancy, non-formal and informal rights, customary rights [which can be of many different types with specific names[, indigenous rights, religious rights, possession, or: no land rights. There may be overlapping tenures, claims, disagreement and conflict situations. This is an extensible list to be filled in with local tenancies - flexible and extensible coding of types of rights and restrictions, etc. is needed. People - land relationships can be expressed in terms of parties having [social[tenure relationships to spatial units. This is in support to access land for all [UN-Habitat, 2008]. It is in support to LA requirements as in [FAO, 2012].

3.1.3. Cadastre 2014

Kaufmann and Steudler [1998], presented characteristics of existing cadastral systems based on a research by a working group Vision 2014 from FIG's Commission 7.The principle of legal independence is a key item in the realization of Cadastre 2014. This means that legal land objects, being subject to the same law and underlying a unique adjudication procedure, have to be arranged in one individual data alyer; and for every adjudicative process defined by a certain law, Figure 3.7. Besides, a special data layer for the legal land objects underlying this process has to be created. In addition, it is claimed that no lonking between layers is needed. A model per layer is valid, e.g. Figure 3.8.

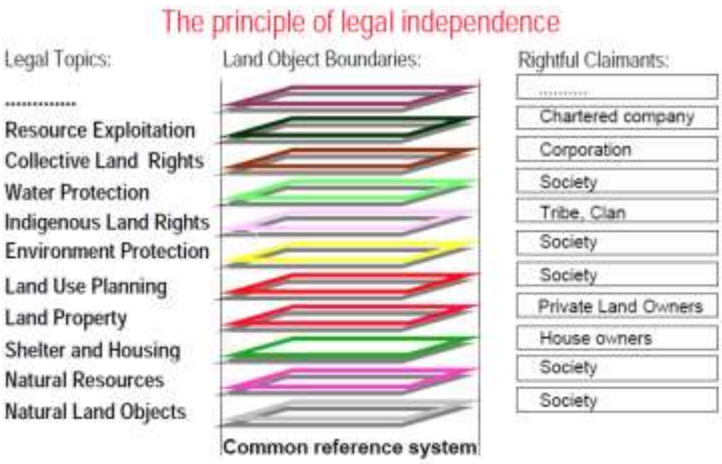


Figure 3.7: Structure of Cadastre 2014 [Kaufmann & Steudler, 1998].

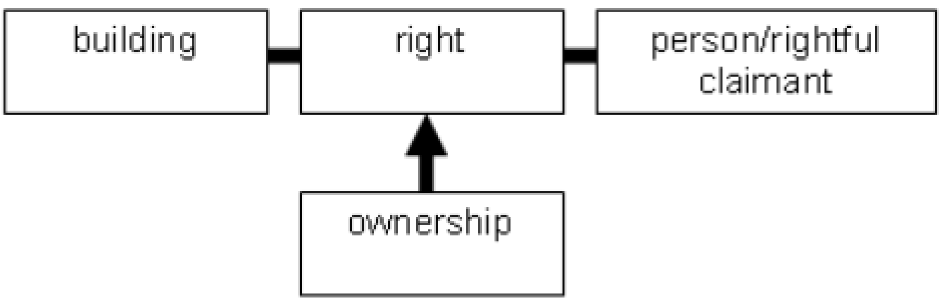


Figure 3.8: Models for buildings as in Cadastre 2014. Parcels are in a separate layer; no links are needed [Kaufmann, 2004].

3.2. Spatial Data Infrastructure

Many countries throughout the world are developing Spatial Data Infrastructures to facilitate better management of their spatial data by taking a perspective that starts at a local level and proceeds through state, national and regional levels to a global level. This has also resulted the development of an SDI hierarchy model in which each SDI at the local level or above is primarily formed by the integration of spatial data sets originally developed for use in corporations operating at that level and below.

Spatial Data Infrastructure is an initiative intended to create an environment in which all stakeholders can cooperate with each other and interact with technology, to better achieve their objectives at different political/administrative levels. SDI initiatives around the world have evolved in response to the need for cooperation between users and producers of spatial data to nurture the means and environment for spatial data sharing and development [McLaughlin & Nichols, 1992; Coleman & McLaughlin 1998; Rajabifard et al., 1999, 2000].

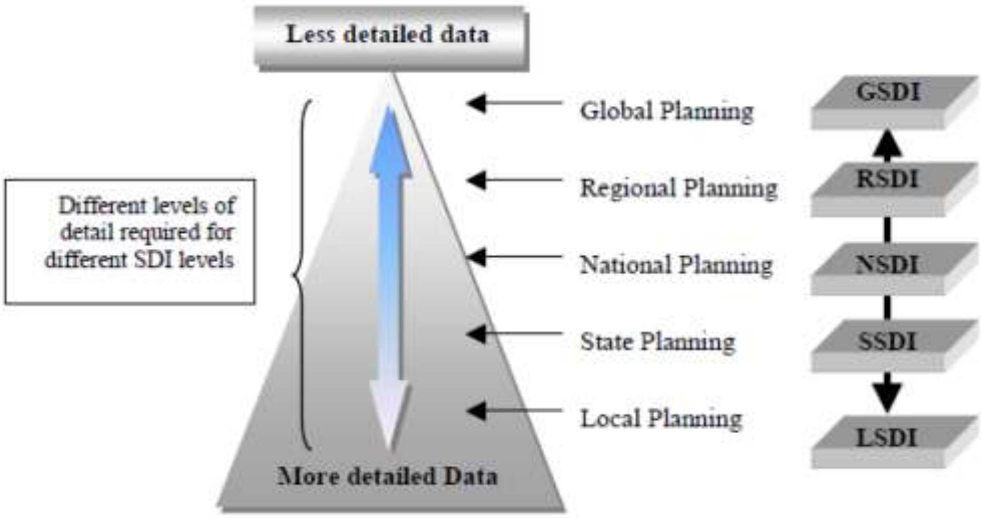


Figure 3.9: Relationship between spatial data and the different level of SDIs [Rajabifard et al., 1999].

The way in which data is collected, stored, maintained and used reflects the institutional and technical background of that particular level or discipline. SDIs at different levels have different drivers that reflect the issues at each particular level and each level of development supports the higher level of development. In general, the various levels are a function of scale. Local government and state-level SDIs manage large- and medium-scale data, leaving national SDIs to manage medium- to small-scale data, with regional and global SDIs adopting a small scale for their activities [see Figure 3.9].

In addition to the vertical relationships between different jurisdictional levels, complex horizontal relationships within each political or administrative level need to be analyzed. The vertical and horizontal relationships within a SDI hierarchy are very complex because of their dynamic inter- and intra-jurisdictional nature. Users of a SDI thus need to understand all the relationships involved in the dynamic partnerships it supports levels and to coordinate spatial data initiatives [http://www.csdila.unimelb.edu.au/sis/Land_Theories/SDI_Hierarchy.html].

An SDI is meant to help avoid fragmentation, gaps in the availability of geographic information, duplication of data collection, and problems of identifying, accessing, or using the available data. An SDI addresses both technical and non-technical issues, ranging from technical standards and protocols, organizational issues, data policy issues including data access policy, to the creation and maintenance of geographic information for a wide range of themes [Van Loenen, 2004].

The GSDI Cookbook [Nebert, 2001] defines SDI as the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. According to this definition, an SDI includes several components:

- geographical information and attributes, organized in distributed repositories,
- documentation of this information [metadata[,
- a means to discover, visualize, and evaluate the data [catalogues and web mapping[,
- some method to provide access to the geographical information,
- a set of agreements with respect to technical [standards[, organizational, and legal issues to coordinate and administer spatial information and services on a local, regional, national, or transnational scale.

Over the last decade, numerous initiatives have been taken to organize the coordination of SDIs on a European scale, either by financing targeted projects, or by establishing SDI coordination bodies and mechanisms on a voluntary basis. Despite these efforts, the fragmentation of spatial information in Europe has increased with increasing spatial data collection.

The concrete elements of the Infrastructure for Spatial Information in Europe follow from the discussions with stakeholders organized through a range of working groups. The following elements are currently envisaged:

- Coordinating structures at EU and Member State level, which organize the practical implementation of the Infrastructure for Spatial Information in Europe.
- Metadata, which describe existing datasets held by public authorities [using agreed standards].
- A linked electronic network, which allows anybody to query, view free of charge, access, and trade the spatial datasets held by public bodies and made available on a voluntary basis by third parties from a single point of [electronic] access through a distributed communications network (the Internet, for example).
- A range of standards for spatial datasets and services, which takes into account existing and emerging European and international standards, and translation services between existing datasets and these standards.
- A data policy framework and a range of sharing agreements between public bodies ensuring that information is exchanged without barriers.
- A framework for the monitoring the implementation of the Infrastructure for Spatial Information in Europe.

INSPIRE is better developed as the European SDI in 3.2.1 and Marine SDI in 3.2.2 as a special category of SDI.

3.2.1. INSPIRE

For cross-border access of geo-data, a European metadata profile, based on ISO standards, is still under development using rules of implementation defined by the Infrastructure for Spatial Information in the European Community, INSPIRE [INSPIRE, 2007]. For actual data exchange, the INSPIRE implementing rules will further define harmonized data specifications and network services. This is complemented with data access policies and monitoring and reporting on the use of INSPIRE [INSPIRE, 2009]. Cadastral parcels is a harmonized dataset, which should serve the purpose of generic information locators for environmental applications, i.e. searching and linking other spatial information.

Directive 1007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community was published and entered into force in May of 2007.

To ensure that the spatial data infrastructures of the Member States are compatible and usable in a Community and trans-boundary context, the Directive requires that common Implementing Rules [IR] are adopted in a number of specific areas: Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting. These IRs are adopted as Commission Decisions or Regulations, and are binding in their entirety [http://inspire.ec.europa.eu].

The INSPIRE Directive requires to take existing standards into account [article 7 of the Directive]. In the case of the LADM, there was an opportunity as both the INSPIRE Cadastral Parcels [CP] and the LADM where under development at the same time. Through joint work, between the INSPIRE Thematic Working Group CP and the LADM Project Team, this has been achieved. This ensured consistency between INSPIRE and LADM, and resulted in a matching of concepts and compatible definitions of common concepts. It must be remembered that there are differences in scope and targeted application areas; e.g. INSPIRE has strong focus on environmental users, while LADM has a multi-purpose character and is supporting both data producers and data users in these various application areas.

Also, LADM has harmonization solutions for rights and owners of 3D spatial units, which are currently also outside the scope of INSPIRE CP. However, through intensive co-operation, it is now made possible that a European country may be compliant both with INSPIRE and with LADM [Lemmen, 2012].

Further, it is made possible through the use of LADM to extend INSPIRE specifications in future, if there are requirements and consensus to do so. In order to "prove" the compatibility, a model was created shown the LADM based version of INSPIRE Cadastral Parcels, explicitly indicating how the INSPIRE development fits within the LADM and that there are no inconsistencies [see Diagram 3.1].

In selecting relevant classes from LADM, using inheritance, adding attributes and constraints it has been possible to express of the INSPIRE Cadastral Parcels data set consistent with LADM. In INSPIRE context, four classes are relevant:

- LA_SpatialUnit (with LA_Parcel as alias) as basis for CadastralParcel;
- LA_BAUnit as basis for BasicPropertyUnit;
- LA_BoundaryFaceString as basis for CadastralBoundary;
- LA_SpatialUnitGroup as basis for CadastralZoning.

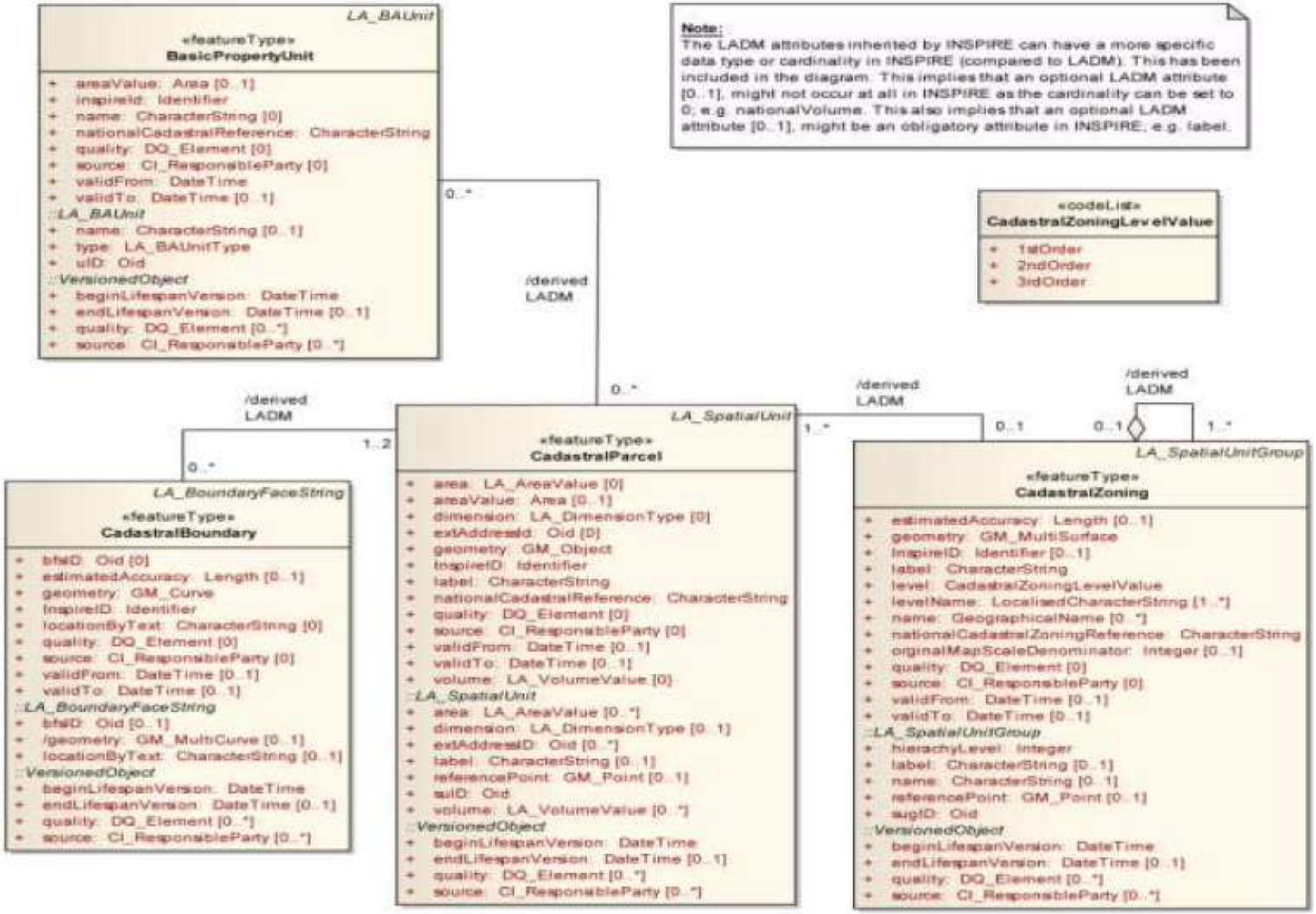


Diagram 3.1: The INSPIRE Cadastral Parcel model derived from LADM via inheritance [Lemmen, 2012

Additionally, INSPIRE has developed some standard styles for data specification in various domains such as cadastre, hydrography, transportation and addresses. For cadastral domains, the document "*Data Specification on Cadastral Parcels Guidelines*" specifies 21 requirements and 29 recommendations for cadastral data [2D parcels] [INSPIRE, 2010]. It addresses issues such as data content and structures, reference systems, data quality, dataset-level metadata and data capture.

I. <u>National Geospatial Information Infrastructure</u>

The implementation of Directive 2007/2/EC by the Greek government starts with the adoption of Law 3882/2010, which sets the legal framework for the establishment of a National Geospatial Information Infrastructure [NGII]. In comparison with other European countries, Greece was faced with a big challenge as geospatial information had been developed in an interoperable way since 2010. Information created by different agencies was characterized by case specific format and limited permission to exchange due to the existing framework and the inadequate cooperation between data producers [INSPIRE, 2013].

Furthermore, the lack of an integrated Cadastre results in a number of interoperability issues. As the parcel is considered as reference data, it is questionable whether all information produced can correctly overlay each other. So the completion of the National Cadastre is of high priority.

3.2.2. Marine Spatial Data Infrastructure [MSDI]

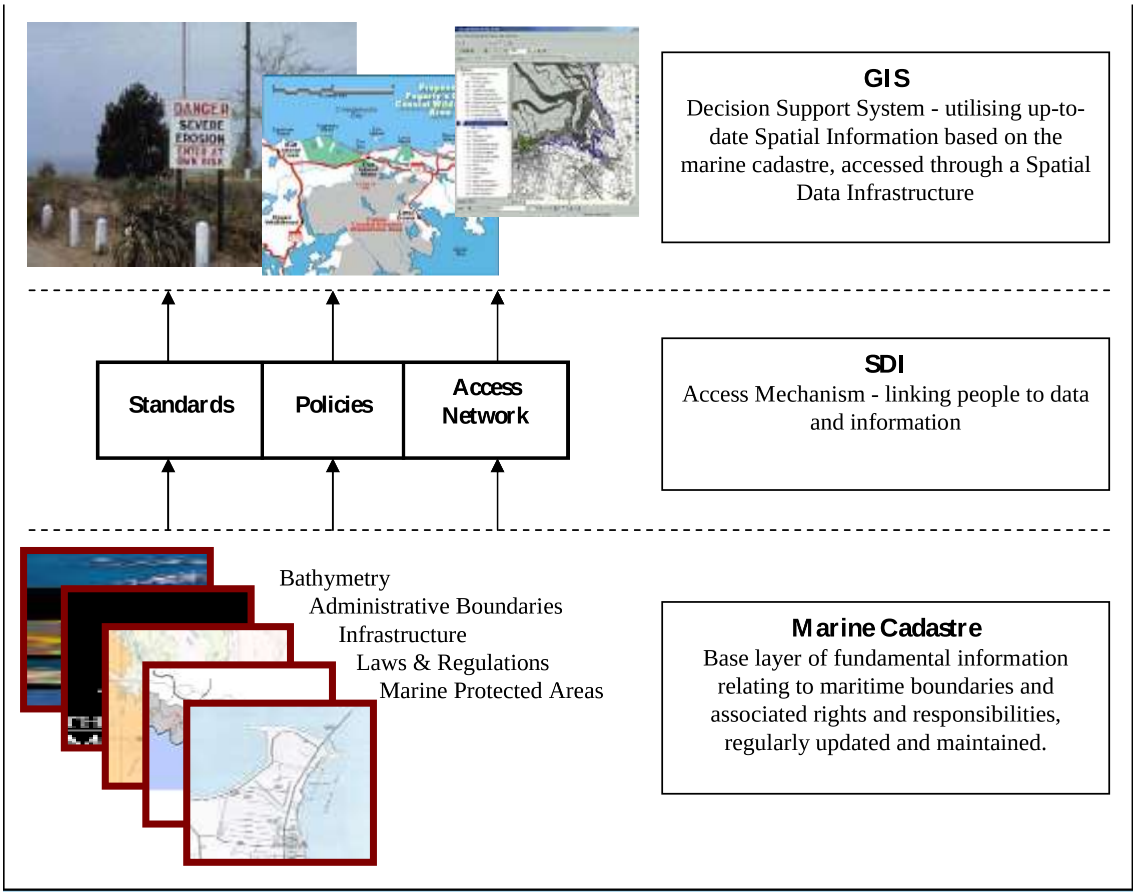
The development of most SDI initiatives throughout the world has focused almost entirely on land. While the concept of marine SDI is relatively new, the idea of supporting marine and coastal management through better access to spatial data or information is more established. Several countries are trying to improve their marine management through improving the accessibility and availability of spatial data. Borrero in the SDI Cookbook states that when developing SDI the following areas need to be considered: definition, objectives, principles, rules and responsibilities, coordination, policies and guidelines [Diagram 3.2]. The SDI should deliver a seamless model that creates a spatially enabled land-sea interface and bridges the gap between the terrestrial and marine environments. Ideally, this would result in harmonized and universal access, sharing, and integration of coastal, marine, and terrestrial spatial datasets across regions and disciplines.

Diagram 3.2: Marine Administration and SDI [Strain et al., 2006].

Comparison between different initiatives for marine administration shows that each one has different aims and ideas, responding to different cultures, levels of development and user needs [Strain et al., 2006]. Most ocean and coastal management problems are of a spatial nature and therefore, the development of a marine component to national and regional SDIs is imperative to the effective management of the marine environment. It is also important to understand the link between the terrestrial and marine environments, recognizing that they cannot be treated as separate entities [Williamson et al., 2010].

The idea of a seamless administration system that covers both the marine and terrestrial environments is generally accepted and noncontroversial. A synchronized SDI is an essential implementation strategy that allows integrated spatial management of interoperable data from both environments. The marine cadastre delivers the fundamental datasets that are especially vital to coastal zone management. The functionality of a cadastre in supporting the SDI is now recognized after a protracted debate about how to use and adapt land-based tools to service marine needs. In modern theory, the cadastral component and the SDI are fundamental to the way marine information is developed and shared, and ultimately for competent marine administration [Williamson et al., 2010].

Diagram 3.3: A marine cadastre and SDI are essential components of effective marine administration [Rajabifard



et al., 2006]

3.3. Standardization in the domain of Land Administration

With respect to spatial data management and interoperability, several standardization initiatives have been set off [e.g. ISO, IAI, Web3D, etc]. After the development of domain-independent standards for spatial and temporal schemas for spatial features [including metadata standards], a next step is the standardization of domain-specific standardized models as basis for standardized the SDIs.

ISO and OGC are the two dominant standards organizations, which develop and publish international standards. ISO [International Organization for Standardization[is an independent, non-governmental membership organization and the world's largest developer of voluntary International Standards. OGC [Open Geospatial Consortium] is an open-member organization, now consisting of 511 active members. It provides free and openly available standards to the market that are of tangible value to OGC Members and have measurable benefits for users. Moreover, OGC produces Abstract Specifications and Implementation Specifications.
[http://www.opengeospatial.org/ogc/members;http://www.iso.org/iso/home/about.htm].

OGC has already started numerous new initiatives to meet the challenges. Currently more than 36 projects are discussing various aspects of data integration and exchange only in the Specification Program and almost all of them attempt to handle the third dimension. The most relevant is the work of CAD-GIS working group [Case, 2005]. The aim of this working group is finding a bridge between CAD, AEC systems and GIS by finding opportunities to improve interoperability of geospatial data and services across these domains. Incompatibilities at various levels (semantic, geometry, topology) contribute to the complexity of the problem [Zlatanova and Prosperi, 2006].

To suggest an appropriate schema for exchange of 3D spatial data, this group will consider several on-going developments, i.e. LandXML, LandGML, CityGML, aecXML [for AEC including information about projects, documents, materials, parts, organizations, professionals, etc.[, TransXML [a project aiming at XML schemas for exchange of transportation data[, IFC [the Industry Foundation Classes used to define architectural and construction-related CAD graphic data as 3D real-world objects[, OpenFlight [an industry standard real-time 3D scene description format[, 3D ShapeFile (ESRI), X3D, etc. [Zlatanova, 2002].

The standards tracks of OGC and ISO are fully coordinated through shared personnel and through various resolutions of ISO TC211 and OGC. They are often complementary and where they overlap, there is no competition, but common action (e.g. in the geometry model). OGC provides fast-paced standard development and promotion of standards adoption, similar to other industry standards consortia such as W3C, IETF, and OMG. ISO is the dominant *de jure* international standards development organization (from now on SDO), providing international government authority important to institutions and stockholders.

Through OGC's cooperative relationship with ISO, many of OGC's OGC Standards either have become ISO standards or are on track to become ISO standards. OGC maintains contact with a number of other standards organizations (W3C, IETF, OMG and others), generally offering expertise related to spatial issues and receiving expertise necessary to ensure that OGC's standards framework is consistent with other IT standards frameworks [http://www.opengeospatial.org/ogc/faq/process].

Examples include International Standards for land cover (ISO 19144-2), Land Administration (LADM, ISO 19152), and Addressing (ISO 19160), all within ISO/TC211, or CityGML [from the OGC, which includes topographic features such as buildings, roads, water and earth surface elevation[or GeoSciML (also from OGC) and both based on GML3 (ISO 19136). The most characteristic examples are described in 3.3.1.

Apart from the OGC and/or ISO standards there are also some standardization initiatives that are not (currently) adopted by any organization. For instance, the 3D Cadastral Data Model (3DCDM) is developed to support integration of legal and physical information that are required for 3D cadastral applications, but is not yet adopted by any SDO.

Last but not least, except for the geo-information standards there are also available many basic standards, such as UML for modeling and XML, GML for exchanging structure information.

At the rest of this chapter, the most dominant and recent standardization initiatives on the domain of land administration are described. In particular, standards from OGC and ISO are presented, followed by initiatives that are not yet adopted by any SDO and also basic geo-information exchange formats are described.

3.3.1. Geo-information exchange formats

I. 3D LandXML

LandXML [http://www.landxml.org] is non-proprietary XML data file was introduced for land survey and construction, initiated in 1999 by Autodesk and EAS-E members. It has been used for exchanging surveying data in land development applications [Crews, 2003]. Government agencies all over the world have been using LandXML as a national standard for cadastral electronic lodgment. Diagram 3.4 illustrates an overview of the LandXML schema. It can also be used for capturing other types of engineering data, such as pipe networks and roadways. The Parcels element itself can be expanded into 2 elements: Parcel and Feature.

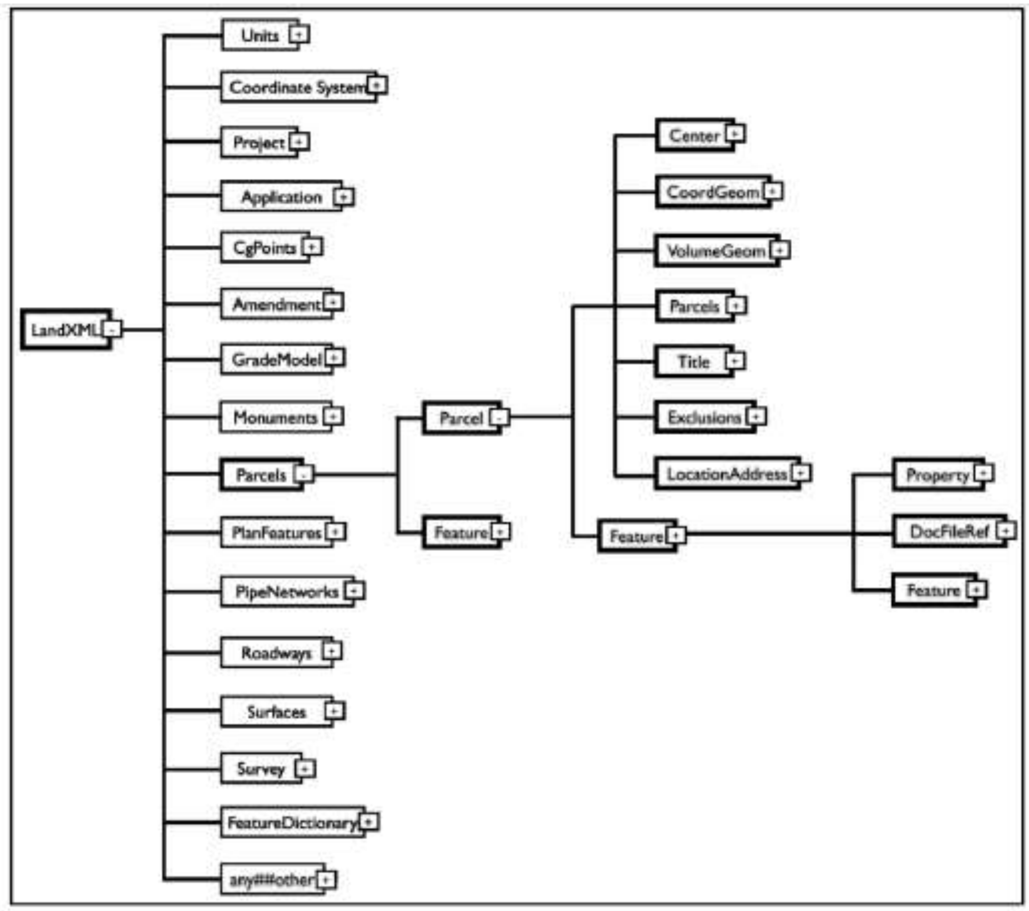


Diagram 3.4: Overview of the LandXML schema with expansion of the Parcels element [www.LandXML.org].

To support 3D Cadastres, the existing LandXML schema is utilized to model 3D parcels. An example of the Parcels element and its sub elements is presented below.

Figure 3.10 illustrates an approach of using the element of PntList3D, which is a sub-element of *IrregularLine* in the LandXML schema. In order to model 3D parcels in Coordinated Cadastre system, a *CoordGeom* represents a face that contains 3D coordinates (Northing, Easting, and Height) in *PntList3D*. A series of faces forms a volumetric parcel (i.e. Parcel "70021N"). The volumetric parcel can be referenced to an external resource as a URI. Alternatively to model 3D parcels in LandXML, one can also use VolumeGeom element, as discussed in Shojaei et. al. [2012].

```xml
▼<Parcel name="70021N/1">
  ▼<CoordGeom>
    ▼<IrregularLine>
       <Start pntRef="433a"/>
       <End pntRef="433a"/>
      ▼<PntList3D>
         29452.018 30232.133 123.280 29452.832 30216.800 123.280 29425.899 30215.278 123.280 29422.375 30281.345
         123.280 29482.916 30284.567 123.280 29484.221 30260.005 123.280 29451.876 30258.266 123.280 29452.008
         30255.922 123.280 29452.207 30250.316 123.280 29451.056 30250.256 123.280 29452.018 30232.133 123.280
       </PntList3D>
     </IrregularLine>
   </CoordGeom>
 </Parcel>
▶<Parcel name="70021N/2">...</Parcel>
▶<Parcel name="70021N/3">...</Parcel>
▶<Parcel name="70021N/4">...</Parcel>
▼<Parcel name="70021N" area="2621.4" parcelFormat="Volumetric">
  ▼<Feature>
     <DocFileRef name="Parcel"
     location="http://wiki.tudelft.nl/pub/Research/ISO19152/ImplementationMaterial/LADMOntology.owl#SpatialUnit"/>
   </Feature>
  ▼<Parcels>
     <Parcel name="Face1" pclRef="70021N/1"/>
     <Parcel name="Face2" pclRef="70021N/2"/>
     <Parcel name="Face3" pclRef="70021N/3"/>
     <Parcel name="Face4" pclRef="70021N/4"/>
```

Figure 3.10: The geometries of 3D parcels in LandXML. A volumetric parcel can be referenced to an external resource as a URI.

The problem of LandXML data format is that currently is not supported by a Standards Developing Organization (SDO) and it is not integrated with any OGC or ISO's geospatial standards. This has resulted in confusion in the marketplace as to the future of the standard as well as the fact that there has not been any work done to advance the standard since 2009. LandXML is used worldwide as a neutral data exchange format by a number of government agencies and private sector firms to share land development, civil, survey and other infrastructure-related data.

Both the land and infrastructure user domain and the geospatial technology user domain would benefit from integrated access to the two types of information. Moreover, with no enhancements in over 5 years, LandXML has failed to keep up with newer methods and software.

The Open Geospatial Consortium Land And Infrastructure Domain Working Group (LandInfraDWG) was chartered in 2013 to "focus on determining how best to integrate and support the LandXML schema within the OGC framework, as well as how to better manage and integrate CAD-based land information with other OGC standards". One of the initial goals of the LandInfraDWG was to gain a better understanding of exactly what LandXML is and does. Its first activity was to reverse-engineer a UML model and documentation; which at the moment are missing; for LandXML-1.2 as a basis for assuming the viability of supporting LandXML as an OGC baseline.

Apart the compatibility problem many technical problems were identified in LandXML; e.g. station data type, weak point typing, case inconsistencies, etc. [Scarponcini, 2013]. Fixing many of these problems will break backwards compatibility; for this reason a new standard is proposed having a use case driven subset of LandXML functionality but implemented with GML and supported by a UML conceptual model.

The new standard is called infraGML and described at the next sub-chapter.

Therefore, a fresh start standard is proposed, which is called InfraGML. This new standard would [Scarponcini, 2013]:

- o be supported by a recognized Standards Developing Organization, OGC,
- o align with existing OGC, TC211 and SQL/MM standards,
- o benefit from functionality already supported by GML, including features, geometry, coordinate reference systems, linear referencing, and surface modeling [TIN[,
- o focus on survey and alignments,
- o using modular extensions, be able to expand into other areas [e.g., pipe networks, parcels, etc.[as resources become available,
- o be use-case driven,
- o be based on a UML conceptual model developed prior to GML [and any other future[encoding
- o have more up-to-date functionality
- o be synchronized with the concurrent efforts by buildingSMART in their development of Infrastructure-based Industry Foundation Classes (IFCs),
- o be more easily integrated with CityGML and TransXML.

InfraGML is the proposed OGC GML application schema supporting land development and civil engineering infrastructure facilities. The OGC has just released the OGC LandInfra Conceptual Model, the first draft of the InfraGML conceptual model for land parcels and the built environment

The alignment part of InfraGML would overlap the recently announced IfcAlignment development work of buildingSMART International [bSI[. The full facility life cycle list of use cases to be supported by InfraGML would be broader than the IfcAlignment focus on design and construction. OGC and buildingSMART can work together on the use case definitions and conceptual model so that the two resultant implementations [IFC and GML[would be harmonized. It is also intended to include recent civil engineering developments such as wider use of 3D modeling.

The resultant IFC version would be consistent with the buildingSMART standards baseline and the GML version would be consistent with the OGC standards baseline. This would enable interoperability within each respective baseline [e.g., IfcAlignment with COBie and InfraGML with CityGML[. The shared conceptual model would allow cross-baseline interoperability [Scarponcini, 2013 http://www.opengeospatial.org/blog/2098, http://geospatial.blogs.com/geospatial/2013/12/a-proposal-to-replace-landxml-with-infragml.html].

The LandInfra UML Packages and their dependencies are shown in the Diagram 3.5. These will approximately align with conformance classes in the InfraGML standard.

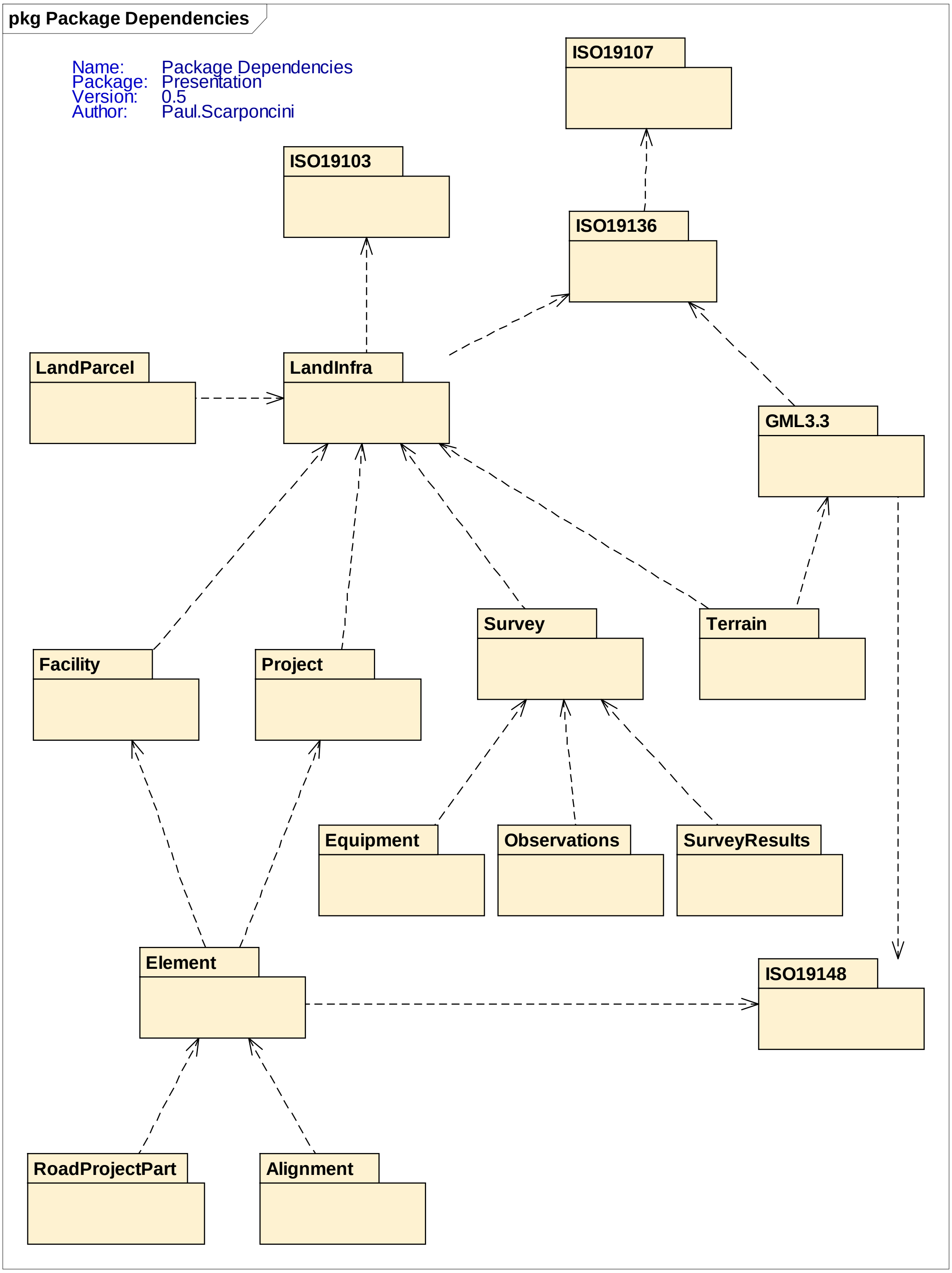


Diagram 3.5: LandInfra UML Packages [Scarponcini, 2013].

For further information related to the context of the packages see OGC [2014].

INTERLIS is a standard for the modeling and integration of geodata into contemporary and future GIS. In Switzerland is the leading tool for describing, integrating and coordinating spatial data and is also listed as Swiss standard SN612031.

INTERLIS is not only targeting the mass market of casual geodata viewers but was specially designed as an answer to the needs of the users and producers [the doers[who are relying on explicitly described geodata structures. Additional properties of this language include being specially adapted to geographic information systems implementability, as well as considerable dedication to practicability and extensibility [http://www.interlis.ch/interlis1/description_e.php].

INTERLIS-1 is a Conceptual Schema Language [CSL] and a neutral Transfer Format [ITF/XTF]. It is an Object Relational [OR] Modeling Language, sufficient for many modeling tasks. It is a very precise, standardized language on the conceptual level to describe data models. Both humans and computers can read it and it has build in data types for GIS-Systems; e.g. the geometry types.

Transfer formats are derived from data models by transfer rules and there is strict separation of transfer and modeling aspects [model driven approach].

The main benefits from INTERLIS are that it:

- Supports freedom of methods through system neutral approach;
- Directly supports the concepts of «Cadaster 2014» [i.e. thematic independent Topics];
- CSL is understandable by IT and domain experts;
- Data can be directly processed and checked by computers.
- Is easy to implementation it.
- Allows the automated quality control of data [checker, check service[
- Allows the automation of many cadaster related processes.
- Provides reference manuals, which are translated to many languages.

Additionally, it has relation with other standards. INTERLIS uses UML as graphic representation of its data models [.ili files]. Moreover, GML is supported by INTERLIS through additional transfer rules [eCH-0118 Standard].

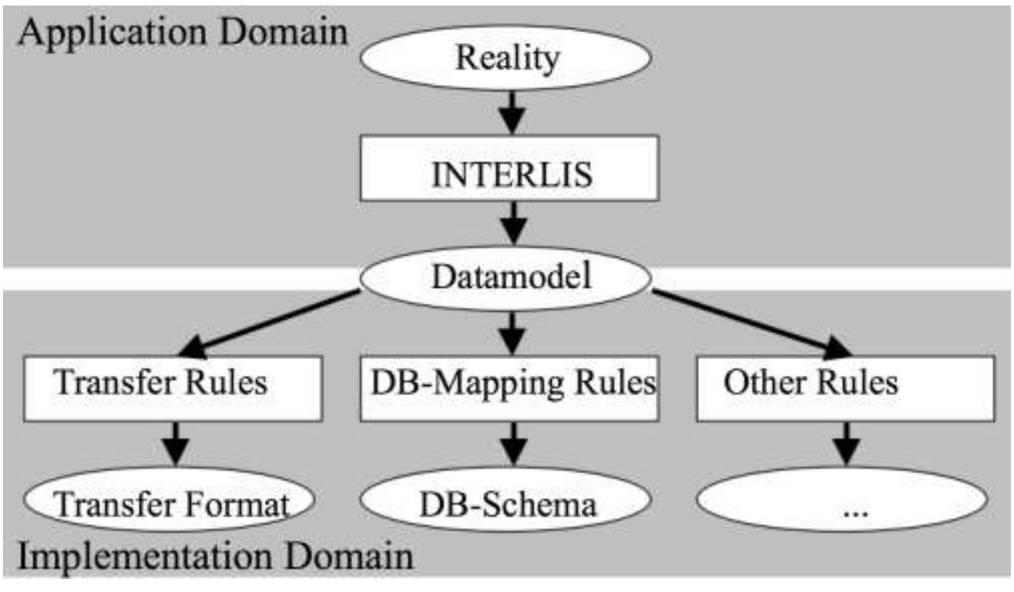


Diagram 3.6: INTERLIS: Language and transfer format [Germann, 2012].

INTERLIS-2 is an Object Oriented [OO] Modeling Language, more flexible but also complex than INTERLIS-1. It supports extension and re-use of existing models and incremental transfer. In this version, XML takes over encoding for the INTERLIS 2 transfer format. XML has become internationally widespread and universally accepted and count on a great number of compatible software products to be obtainable in the near future. The two versions are compatible with each other. The most important is that constraints can be specified formally and explicitly, as they are not defined as individual, independent objects but as structures [Germann, 2012].

IV. Industry Foundation Classes

The Industry Foundation Classes [IFC] data model is intended to describe building and construction industry data. It is an object-oriented data model based on class definition representing the things [elements, processes, shapes, etc.] that are used during a construction or facility management project. The model focuses on the classes that need to share information rather than processing it in particular proprietary software.

IFC is a neutral and open specification developed by buildingSmart International[1] that is not controlled by a vendor or a group of vendors. It was created to facilitate interoperability in the architecture, engineering and construction (AEC) industry [http://www.ifcwiki.org/index.php/Basic_Informations].

IFC constitutes an open specification, listed as ISO 16739 [IAI, 2008] and defines an "entity-relationship" model providing an abstract and conceptual representation of data. It consists of 900 entity classes organized into an object-oriented hierarchy and provides detailed semantics for the building's construction elements [Goetz & Zipf, 2011].

It is registered by ISO and is an official international ISO 16739:2013. IFC together with CityGML can be used for the representation of cadastres in three dimensions. The IFC conceptual schema and the specifications are written using the EXPRESS data definition language, defined as ISO 10303-11 by the ISO TC184/SC4 committee. EXPRESS adopts many object-oriented concepts, including multiple inheritances. It has the advantage of being compact and well suited to include data validation rules with the data specification.

IFC data files are exchanged between applications using the following formats and should be indicated as .ifc; .ifcXML; .ifcZIP.

1 BuildingSmart is an international organization which aims to improve the exchange of information between software applications used in the construction industry. It has developed IFC and BIM.

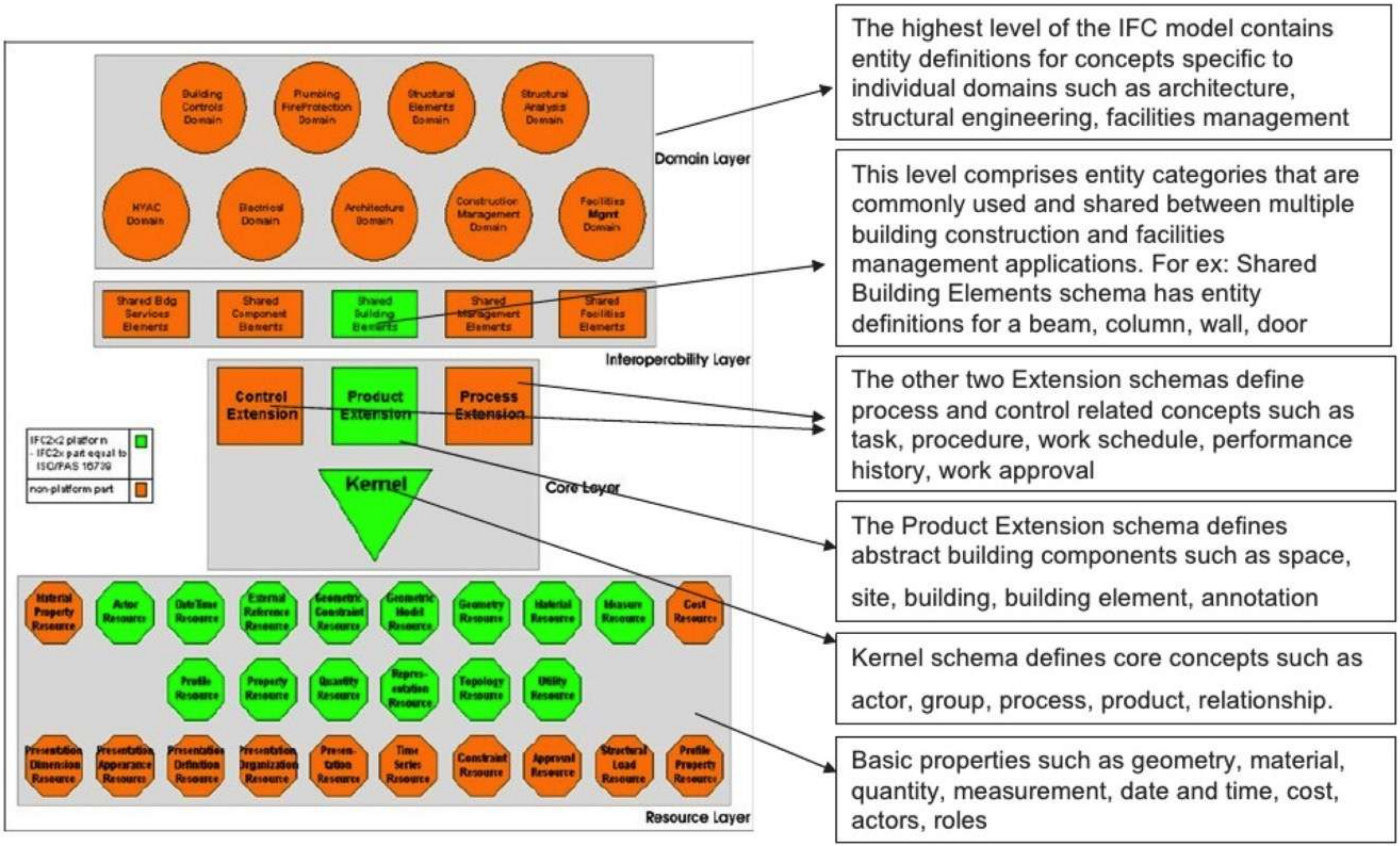


Diagram 3.7: Industry Foundation Classes [http://paginas.fe.up.pt/~gequaltec/w/index.php?title=Industry_Foundation_Classes]

3.3.2. Standardization initiatives for domain models

I. Building Information Model [BIM]

The need of integrating semantic data for cadastral purposes has increased popularity of modeling approaches that support semantic characteristics such as BIM employing Industry Foundation Classes (IFC) standard.

The core requirement of Building Information Model (BIM) for complex building projects, mainly in Europe and the United States, may facilitate, to some extent, 3D property presentation [NBIMS, 2006]. According to [Isikdag et al., 2013], BIM is a digital version of all the functional features of a building through its entire life cycle [Diagram 3.8]. In other words, BIM refers to a representation of the building parts regarding at the same time their geometric and semantic aspects.

CityGML and IFC are related but at the same time they vary in many aspects. Summarizing the most important difference of them is the different way according to which 3D models are acquired in each of the models, which lead to different definition of the same semantic object, as presented in Figure 3.11. BIM models represent how 3D objects are constructed, while the objects in IFC models are described by their observable surfaces based on modeling principles [Nagel et al., 2009].

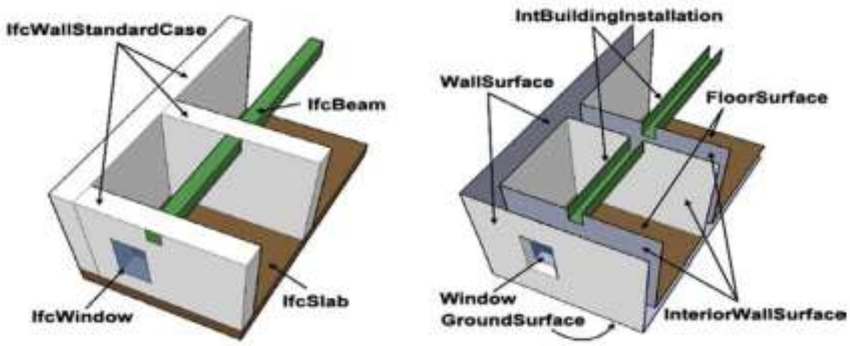


Figure 3.11: A building part modeled in IFC [left] and in CityGML [right] [Nagel et al., 2009].

BIM has evolved in the construction domain, whereas 3D property has evolved in the legal cadastral domain. Although it seems that they are two different domains, El-Mekawy et al. [2014] argue that they can interact. BIM is considered as an object-oriented process, which describes buildings in respect to their geometric and semantic properties. It therefore involves the generation as well as management of spatial digital representations of physical and functional characteristics of building spaces and their surrounding environment [Isikdag & Zlatanova, 2009a].

Such models are less capable to visualize topographic features and RRRs, as they are optimal for analysis on building level and cannot accommodate 3D cadastral purposes in full scale. However, research towards integration of BIM models with GIS characteristics through GeoBIM [De Laat & Van Berlo, 2011] can enhance BIM's contribution to 3D Cadastre purposes.

Today, there is no interaction between BIM and the 3D property management. BIM can add to improve the real property formation, registration and visualization process. However, according to El-Mekawy et al. [2014] there are some problems to be addressed. For instance, there is increased use of geographical information standards and LASs do not make use of all of them, or maybe there is no compatibility between all of them.

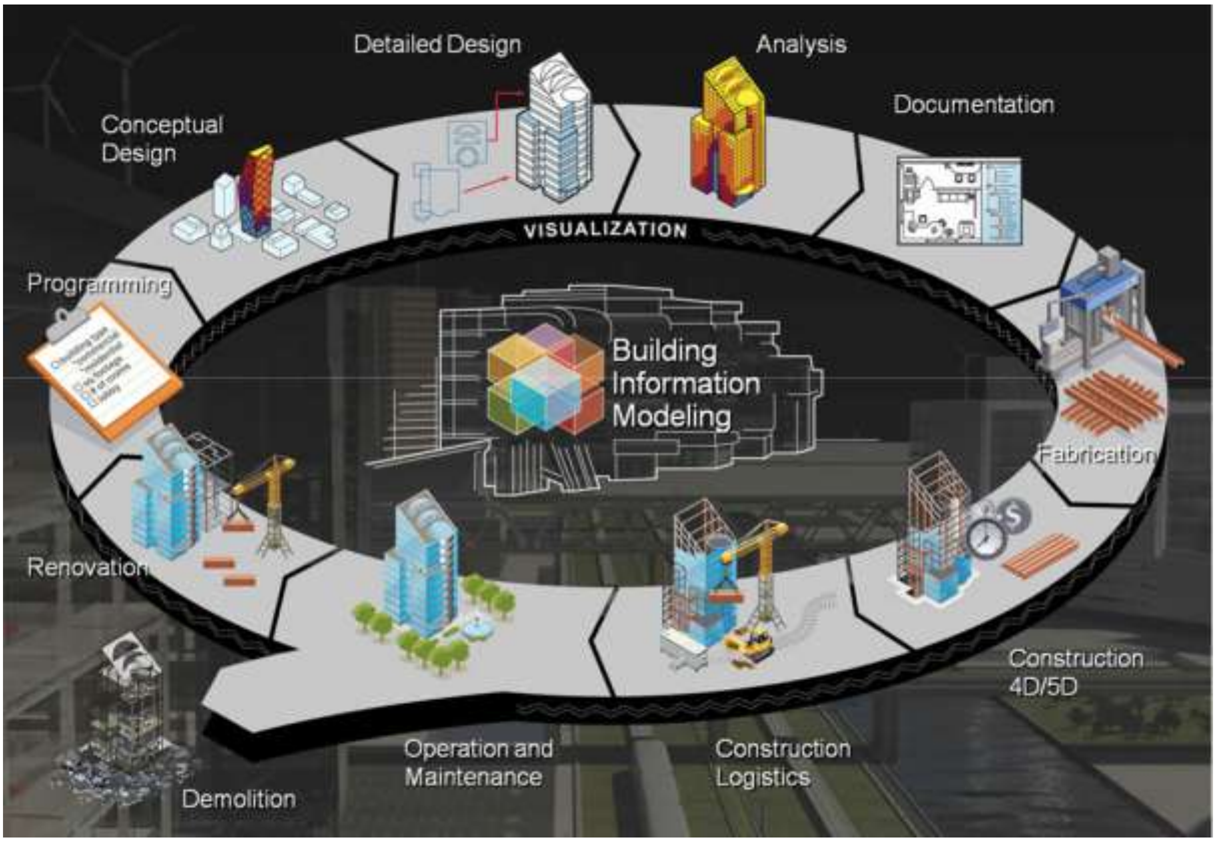


Diagram 3.8: What is BIM? [National Defence Canada, 2012]

II. CityGML

The CityGML standard is an Open Geospatial Consortium encoding standard since August 2008 [republished in version 2 in March 2012], which describes physical reality. It allows for a complete 3D visualization of the real world objects including their semantic, geometrical, topological and appearance characteristics in different levels of detail [LoD] depending on application [Kolbe, 2007].

As reported in [www.citygml.org] CityGML is defined as follows: "*CityGML is a common information model and XML-based encoding for the representation, storage, and exchange of virtual 3D city and landscape models, …. CityGML is implemented as an application schema for the Geography Markup Language version 3.1.1 [GML3], an official extendible international standard for spatial data exchange issued by the Open Geospatial Consortium [OGC] and the ISO IC211. Because CityGML is based on GML, it can be used with the whole family of GML compatible OGC web services for data accessing, processing, and cataloging like the Web Feature Service, Web Processing Service, and the Catalog Service. CityGML is an open standard that can be used free of charge.*"

Apart from its coherent semantic and geometrical design principles, CityGML is a data model comprising, among others, DTM, buildings and building parts, tunnels, water bodies and land use [Gröger et al., 2012].

CityGML model as presented in [Kolbe et al., 2005], is a multi-purpose, unified information model that uses a semantic-based objects hierarchy expressed by classes and associations for the most relevant (city) features from different thematic groups. In particular, CityGML defines the geometric information about layers for water bodies, buildings, vegetation, terrain, etc, represented by basic geometric objects (point, line, polygon) tohether with the corresponding thematical;, semantical and appearance properties.

The fact that CityGML is XML based makes it an easily interchangeable data exchange format as well as it enables the interoperability among many applications.

CityGML supports 5 different levels of details covering also semantic aspects, starting from LoD0 to LoD4 [indoor, see Figure 3.12] amongst which the most prominent are the LoD of buildings [Zlatanova et al., 2012].

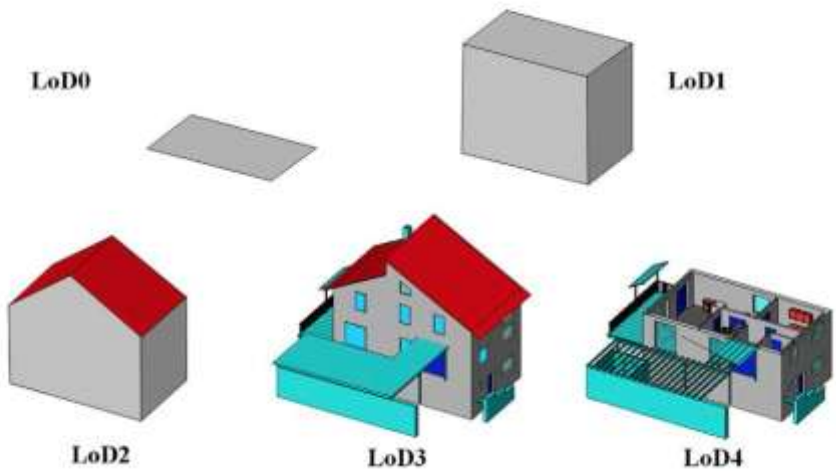


Figure 3.12: The five Levels Of Details defined by CityGML [LoD], [KITGröger et al., 2012].

CityGML can be extended to include additional data features and attributes, and thus provide semantic modeling for 3D Cadastre. However, there is still a large gap between the geometry data in CityGML data and 3D property unit. This is due t the fact that, CityGML focuses on the appearances and the shapes of the landscape and buildings with physical realities, focused on the visualization of the external physical surface of the city objects. These data have not reached the requirements of 3D property unit, which is the basic unit of city management and applications [Guo, 2012].

Although 3D property unit and CityGML are similar to some extent, the specific geometric data of them are in a tremendous difference. So making the correspondence rules of the data model between them and finding the needed geometry data to be handled further are the keys to convert CityGML data to 3D property unit.

According to Ying et al. [2014], 3D property unit has basic triple elements:

- The semantic and ownership information,
- The spatial information and
- The RRRs.

The mainly described objects in CityGML are buildings with different Levels of Details [LoDs]) and precisions; which are different in terms of complexity and granularity of the geometric representation. According to the same authors, LoD2 and LoD3 are more relate to the real estate and 3D cadastre. The semantic objects that are related with 3D property unit in CityGML are shown in Table 3.1. They developed a methodology to convert CityGML data to 3D property units based on semantic and geometric transformation. This method can be also used as data source for a wide range of 3D city modeling and spatial analysis; as applications based on CityGML refer to the wider thematic areas of: urban development, energy management, property taxation, navigation (indoor as well), natural disasters simulation, cultural heritage registration and military operations.

Objects	LoD1	LoD2	LoD3	LoD4
BuildingFurniture	--	--	--	x
CeilingSurface	--	--	--	√
ClosureSurface	--	--	--	√
Door	--	--	√	x
FloorSurface	--	--	--	√
GroundSurface	√	√	√	√
IntBuildingInstallation	--	--	--	x
InteriorWallSurface	--	--	--	x
RoofSurface	√	√	√	√
Room	--	--	--	x
RoomInstallation	--	--	x	x
WallSurface	√	√	√	√
Window	--	--	x	x
the objects except buildings	x	x	x	x

(Note: "--" indicate that there are no such objects in this LoD, "√" indicates that this object is included in this LoD and needed for constructing 3D property unit, "x" indicates that this object is not used to construct 3D property unit.)

Table 3.1: The semantic objects related with 3D property unit in CityGML [Ying et al., 2014].

III. Social Tenure Domain Model [STDM]

The Social Tenure Domain Model is a specialization of the LADM and has been introduced in order to cover all types of tenures, conventional and other social tenures such as informal and customary [Augustinus et al., 2006; Augustinus, 2010; Lemment et al., 2007; FIG, 2010]. It has its own terminology and it complements the LADM. It is developed by UN Habitat, the International Federation of Surveyors, the World Bank and the University of Twente, Faculty (ITC). STDM broadens the scope of land administration. ITC was then financially supported by the Global Land Tool Network to develop the technical aspects of STDM.

The Global Land Tool Network (GLTN) is a coalition of international organizations who have agreed on an agenda of 18 pro poor land management tools for urban and rural areas [www.gltn.net]. Most tools are national but have rural and urban applications. These tools are being developed by the partners not just as tools on their own, but also linked to cross cutting issues such as gender, the involvement of the poor users, land governance, and the need for capacity building. The continuum of land rights (which is about the incremental acquisition of rights over time), and STDM are two of the GLTN tools.

The STDM is a multi-partner software development initiative to support pro-poor land administration. The initiative is based on open source software development principles. The STDM, as it stands, has the capacity to broaden the scope of land administration by providing a land information management framework that would integrate formal, informal, and customary land systems and integrating administrative and spatial components. The STDM makes this possible through tools that facilitate recording all forms of land rights, all types of rights holders and all kinds land and property objects / spatial units regardless of the level of formality.

Not only with regard to formality does the thinking behind the STDM depart in terms of going beyond some established conventions. Traditional or conventional land administration systems, for example, relate names or addresses of persons to land parcels via rights. An alternative option being provided by STDM, on the other hand, relates personal identifiers such as fingerprints to a coordinate point inside a plot of land through a social tenure relation such as tenancy. The STDM thus provides an *extensible* basis for efficient and effective system of land rights recording.

Furthermore, it integrates administrative and spatial components. In particular, the model describes relationships between people and land in an unconventional manner; it has the power to tackle land administration needs in communities, such as people in informal settlements and customary areas. It supports development and maintenance of records in areas where regular or formal registration of land rights is not the rule. It focuses on land and property rights, which are neither registered nor registerable, as well as overlapping claims, that may have to be adjudicated both in terms of the 'who', the 'where' and the 'what right'.

In other words, the emphasis is on social tenure relationships as embedded in the continuum of land rights concept promoted by GLTN and UN-HABITAT. This means informal rights such as occupancy, adverse possession, tenancy, use rights (this can be formal as well), etc or customary rights, indigenous tenure, etc as well as the formal ones are recognized and supported [with regard to information management[in STDM enabled land administration system [Lemmen et al., 2009].

Likewise, the STDM accommodates a range of spatial units ['where', e.g. a piece of land which can be represented as one point – inside a polygon, a set of lines, as a polygon with low/high accuracy coordinates, as a 3D volume, etc.[. Similarly, the STDM records all types of right holders ("Who", e.g., individuals, couples, groups with defined and non-defined membership, group of groups, company, municipality, government department, etc.).

In regard to evidence, STDM handles the impreciseness and possible ambiguities that may arise in the description of land rights. In a nutshell, the STDM addresses information related components of land administration in an innovative way [Lemmen & Van Oosterom, 2013].

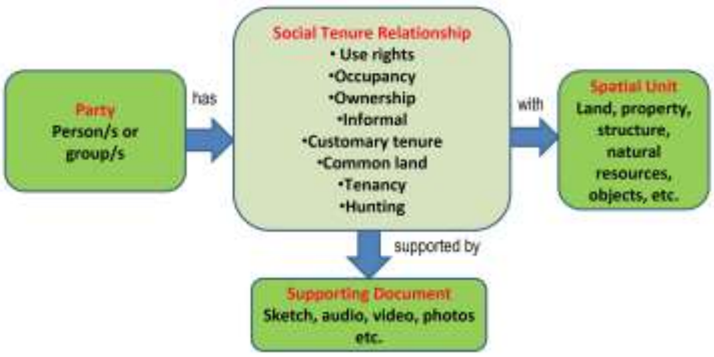


Figure 3.13: Core conceptual diagram of STDM [Linkages between Core Cadastral Model, LADM and STDM, UN-HABITAT, 2013].

Moving away from individual freehold parcel based tenure systems and adopting a range of rights and claims in order to extend security of tenure to more people, including the poor, implies that a new form of land administration has to be designed. Adopting a continuum of land rights made the land administration technical gap obvious, which technical gap is covered by STDM [Augustinus, 2010].

IV. Land Administration Domain Model [LADM]

The LADM was approved as an official International ISO Standard on November 1st, 2012 [ISO 19152:2012]. It covers basic information-related components of land administration (including those over water and land and elements above and below the surface of the earth). The model provides a conceptual schema with three basic packages and one sub-package:

1. parties, which means people and organizations that perform transactions,
2. basic administrative units, including rights, restrictions and responsibilities,
3. spatial units, mostly parcels and the legal space of buildings and utility, surveying and spatial representation.

As it happens with other models, the scope of LADM is limited, and cannot therefore model the whole world. However, certain object classes outside its scope are relevant and should be referred to. There is the possibility to create external classes when needed and use population registers (or other sources) as an external reference [Lemmen, 2012]. LADM will be further analyzed in 3.3.4.

3.3.3. Standardization initiatives that are not yet adopted by SDO

I. 3D Cadastral Data Model (3DCDM)

A 3D cadastral data model (3DCDM) aims to achieve a conceptual framework for 3D cadastres. It was developed to support integration of legal and physical information that are required for 3D cadastral applications. The first version (3DCDM_Version 1.0) has the following core classes,: 3DCDM_InterestHolder, 3DCDM_PropertyObject (PO), 3DCDM_Geometry, 3DCDM_urvey, 3DCDM_SurveyPoints, 3DCDM_SurveyObservation and 3DCDM_ExternalSources (Diagram 3.9).

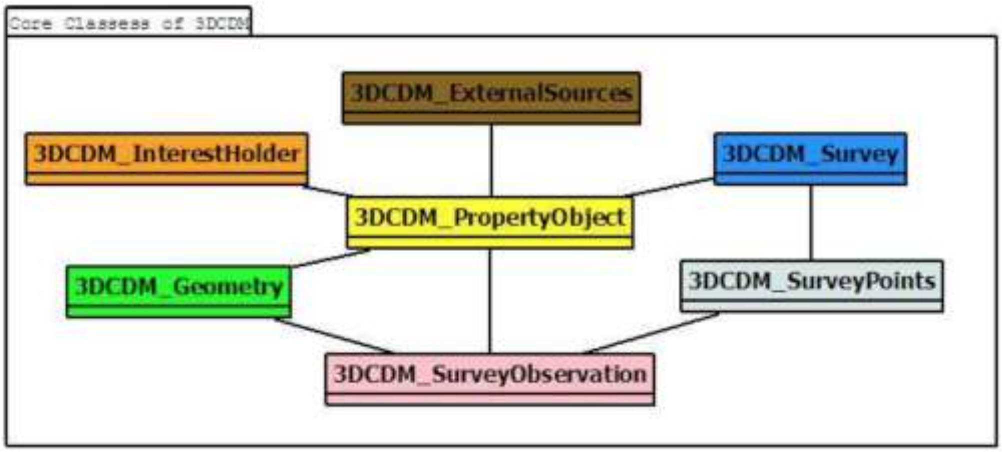


Diagram 3.9: Core classes of 3DCDM [Aien A et al, 2012].

The 3DCDM model has twelve sub-models or modules, which are selected based on the user requirements and the application. It has two important components; the PhysicalPropertyObject and the LegalPropertyObject.. Based on these concepts, the 3DCDM has two hierarchies, legal and physical which are linked at the model.

- *LegalPropertyObject*: It allows for the representation of spatial aspects of legal objects (2D and 3D(. The UML diagram of the LegalPropertyObject model is depicted in Diagram 3.10. In this model all land interests: rights, restrictions, and responsibilities are represented.
- *PhysicalPropertyObject:* having separated this concept facilitates selection of the appropriate PhysicalPropertyObject for any particular application.

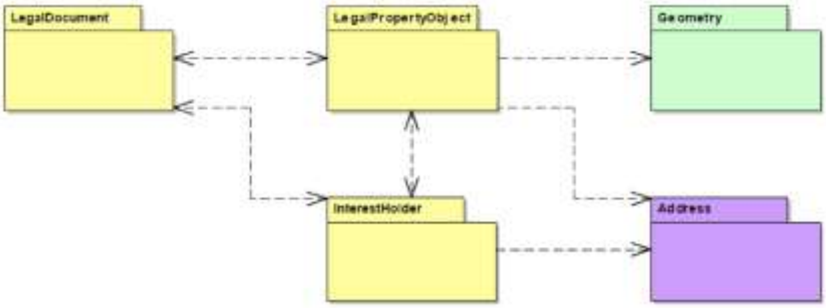


Diagram 3.10: UML diagram of 3DCDM's LegalPropertyObject model [Kalantari et al., 2008].

In Diagram 3.11, the conceptual model of integrating the legal and physical objects is presented.

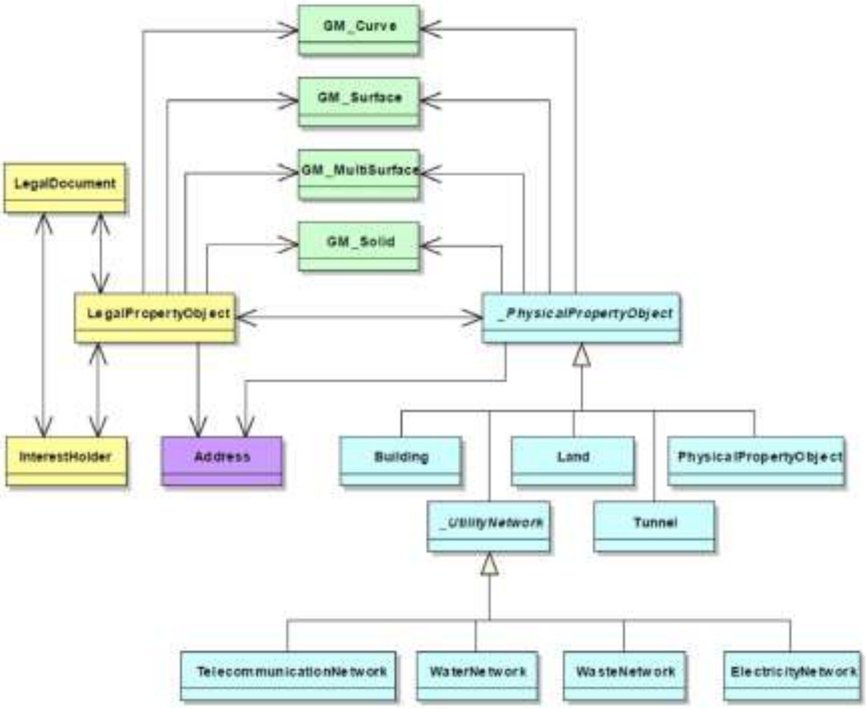


Diagram 3.11: Conceptual model of integrated legal and physical objects in the 3DCDM model [Aien et al., 2013].

3.3.4. Land Administration Domain Model [LADM]

I. <u>Conceptual model</u>

Domain specific standardization is needed to capture the semantics of the land administration domain on top of the agreed foundation of basic standards for geometry, temporal aspects, metadata and also observations and measurements from the field. A standard is required for communication between professionals, for system design, system development and system implementation purposes and for purposes of data exchange and quality management of data.

Such a standard will enable GIS and DBMS providers and/or open source communities to develop products and applications for Land Administration purposes. And in turn this will enable land registry and cadastral organizations to use the components of the standard to develop, implement and maintain systems in an even more efficient way [Lemmen & Van Oosterom, 2013].

Internationally, the wish emerged for a widely accepted standardized domain model, making use of the collective knowledge already existing worldwide. This wish was supported by the FIG and UN-Habitat and also by the FAO of the UN. The data model should be able to function as the core of any land administration system. The standard should be flexible, widely applicable and function as a gathering point of a state-of-the-art international knowledge base on this theme.

The development of LADM is based on user needs; comprehensive overview of requirements for the Land Administration Domain is available in [Lemmen, 2012]. Open markets and globalization require a shared ontology allowing enabling communication between involved persons within one country and between different countries. Effective and efficient system development and maintenance of flexible (generic) systems ask for further standardization.

The conceptual model of LADM is presented in Diagram 3.12. The main class of the party package of LADM is class LA_Party with its specialization LA_GroupParty. There is an optional association class LA_Party-Member. A Party is a person or organization that plays a role in rights transaction. An organization can be a company, a municipality, the state, or a church community. A 'group party' is any number of parties, forming together a distinct entity. A 'party member' is a party registered and identified as a constituent of a group party. This allows documentation of information to membership (holding shares in rights).

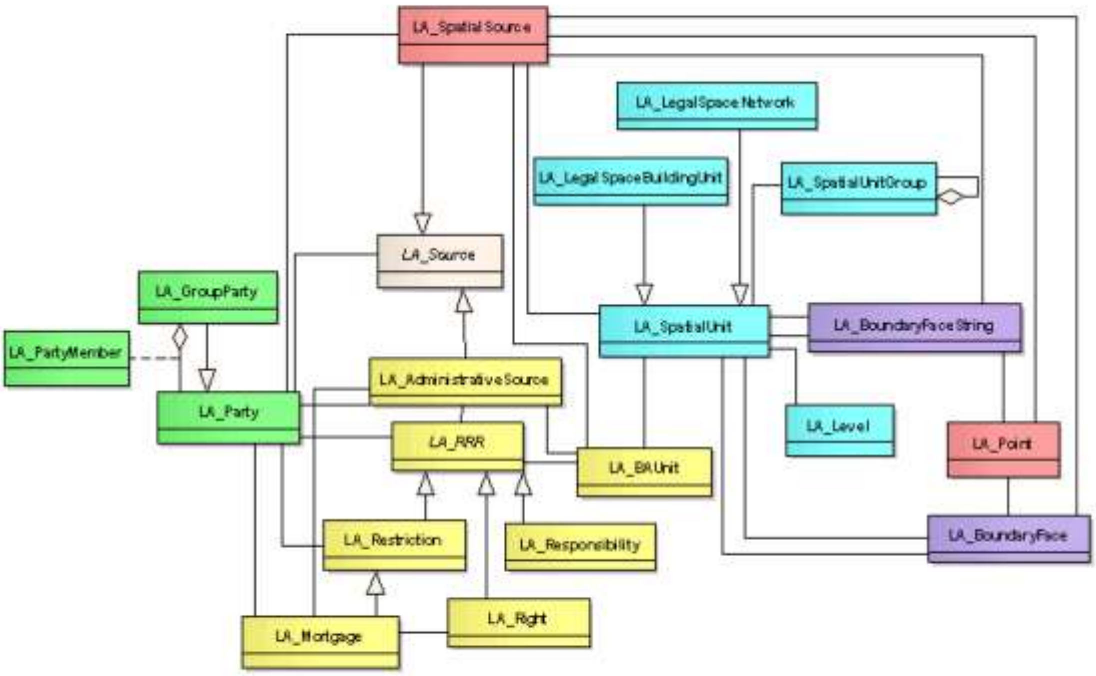


Diagram 3.12: The Land Administration Domain Model [Lemmen, 2012].

The administrative package concerns the abstract class LA_RRR (with its three concrete subclasses LA_Right, LA_Restriction and LA_Responsibility(, and class LA_BAUnit (Basic Administrative Unit(. A 'right' is an action, activity or class of actions that a system participant may perform on or using an associated resource. A right can be an (informal(use right. Rights may be overlapping or may be in disagreement. A 'restriction' is a formal or informal entitlement to refrain from doing something; e.g. it is not allowed to build within 200 meters of a fuel station; or servitude or mortgage as a restriction to the ownership right. A 'responsibility' is a formal or informal obligation to do something; e.g. the responsibility to clean a ditch, to keep a snow-free pavement or to remove icicles from the roof during winter or to maintain a monument.

A 'baunit' (an abbreviation for "basic administrative unit") is an administrative entity consisting of zero or more spatial units (parcels) against which one or more unique and homogeneous rights (e.g. an ownership right or a land use right) responsibilities or restrictions are associated to the whole entity as included in the Land Administration System. A "basic administrative unit" may play the role of a 'party' because it may hold a right of easement over another, usually neighboring, spatial unit.

The spatial unit package concerns the classes LA_SpatialUnit, LA_SpatialUnitGroup, LA_Level, LA_LegalSpaceNetwork, LA_LegalSpace-BuildingUnit and LA_Required-RelationshipSpatialUnit. LADM defines 5 levels of encoding the geometry, based on the level of maturity:

I. Text based encoding
II. Point based encoding
III. Line based encoding
IV. Polygon based encoding
V. Topology based encoding

All the levels of encoding within the LADM are available to be used with 3D cadastre. It might be unusual to consider the lower-level encodings, (such as line-based), but it should be noted that the commonly used "building unit" form of 3D spatial unit is in effect a text based spatial unit.

There is also a fairly common combined approach - where the floor plan of the unit is defined geometrically, but the only elevation information is textural - such as "on floor 5". Three-dimensional parcels occur commonly in areas of high property values, and in these areas, the accuracy of survey likewise tends to be higher. Further, it is easier to justify the costs of careful data encoding in these regions. It is easy to envisage a cadastre consisting of a mixture of 2D and 3D parcels using a high level of encoding in the city areas, combined with low-level encoding of lower accuracy information in less dense regions (Thompson, 2013).

Spatial units are structured in a way to support the creation and management of basic administrative units. A 'level' is a collection of spatial units with a geometric and/or topologic and/or thematic coherence.

LADM defines a 3D parcel as the spatial unit against which (one or more(unique and homogeneous rights (e.g. ownership right or land use right(, responsibilities or restrictions are associated to the whole entity based on ISO 19152 (Thompson & Van Oosterom, 2011). Spatial units (synonym of parcels(have two specializations: legal spaces buildings and legal spaces networks.

The Spatial Unit Package has one Surveying and Spatial Representation Sub-package with classes such as LA_SpatialSource, LA_Point, LA_BoundaryFaceString and LA_BoundaryFace. Points can be acquired in the field by classical surveys or with images. A survey is documented with spatial sources. A set of measurements with observations (distances, bearings, etc.(of points, is an attribute of LA_SpatialSource. The individual points are instances of class LA_Point, which is associated to LA_SpatialSource. 2D and 3D representations of spatial units use boundary face string (2D boundaries implying vertical faces forming a part of the outside of a spatial unit) and boundary faces (faces used in 3D representation of a boundary of a spatial unit(. All classes (except LA_Source) inherit from VersionedObject.

VersionedObject contains quality labels and attributes for history management. In the LADM, administrative sources and spatial sources are modelled, starting with an abstract class LA_Source. LA_Source has two subclasses: LA_AdministrativeSource, and LA_SpatialSource. External links to other databases [supporting information infrastructure type of deployment], e.g. addresses, are included, as shown in Diagram 3.13.

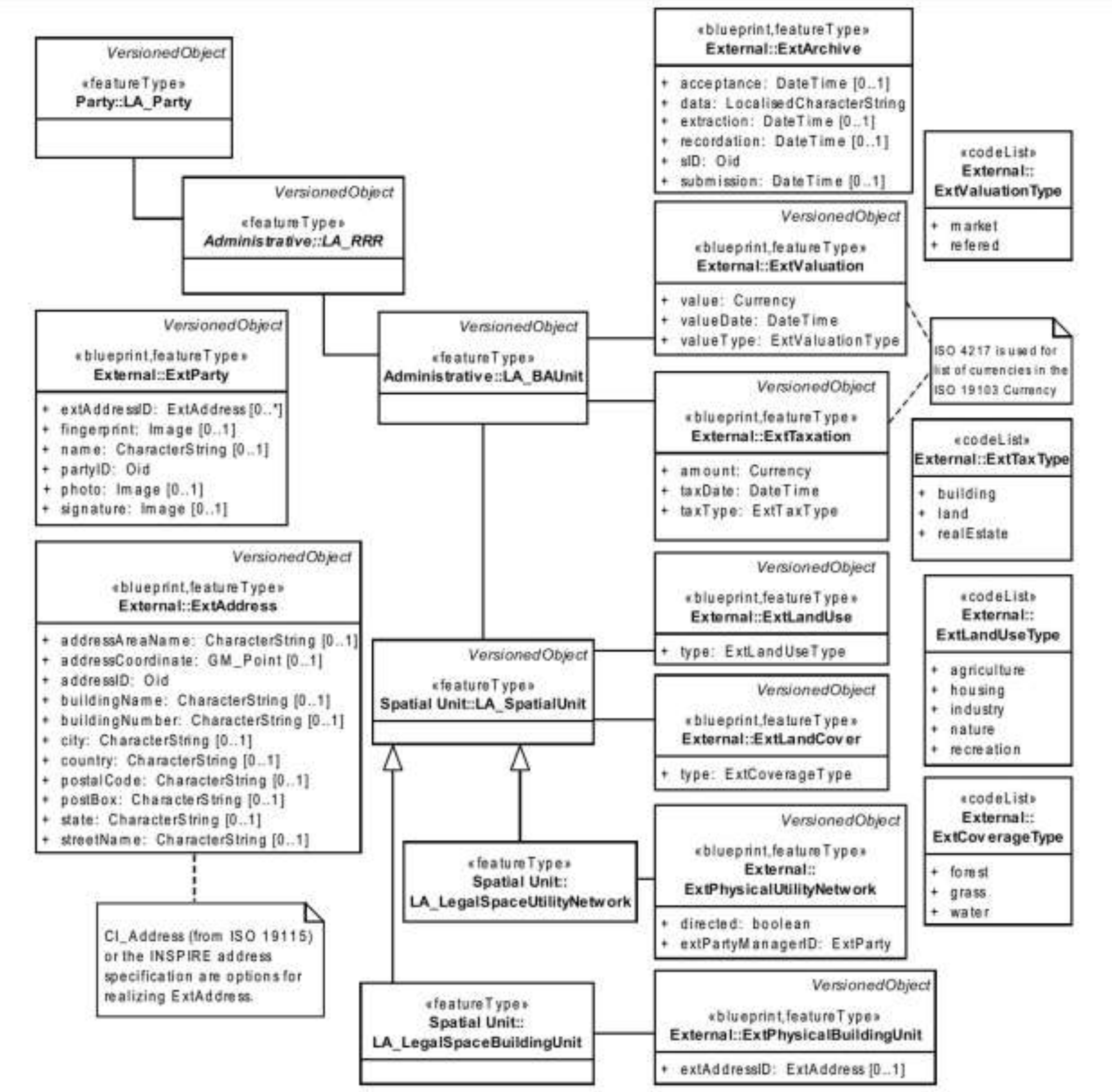


Diagram 3.13: LADM and external classes [ISO 19152, 2012].

Class VersionedObject is introduced to LADM to manage and maintain historical data in the database; by introducing a time-stamp for the inserted and superseded data. As presented in Diagram 3.14, all the LADM classes are subclasses of class VersionedObject apart form the abstract class, LA_Source and the two subclasses: LA_AdministrativeSource and LA_SpatialSource; see Diagram 3.15.

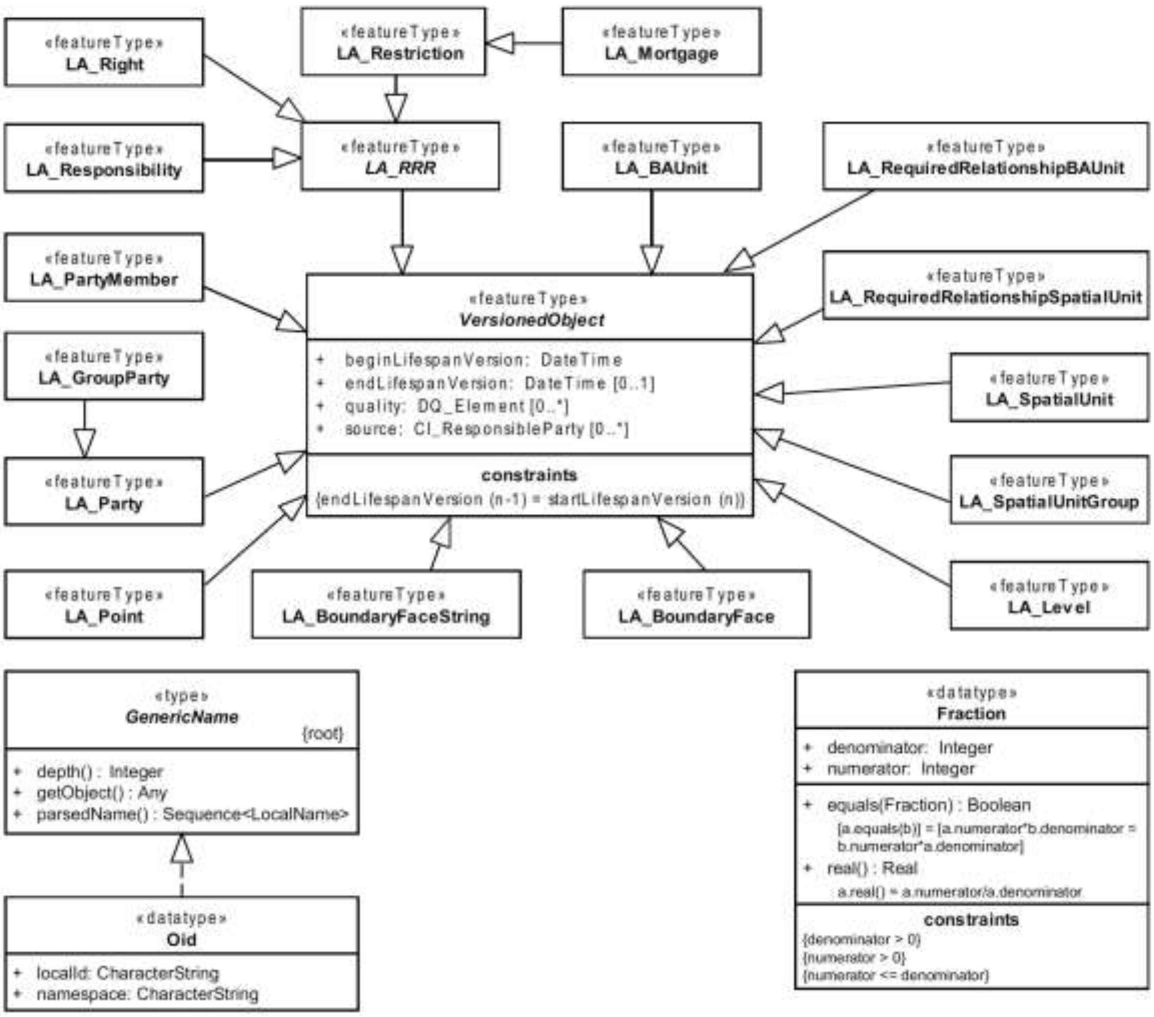


Diagram 3.14: LADM classes VersionedObject with subclasses [ISO 19152, 2012].

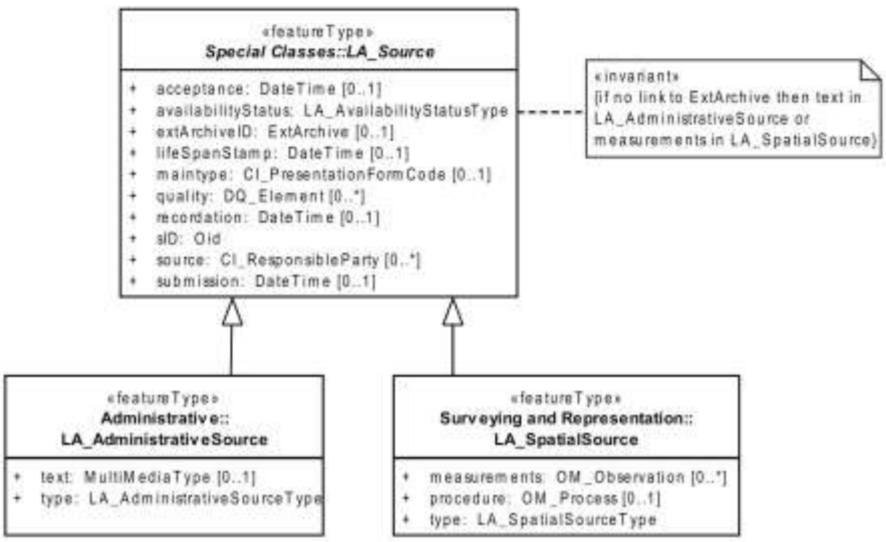


Diagram 3.15: LADM Class LA_Source with subclasses [ISO 19152, 2012].

II. Imported functionality from other standards

LADM makes use of a number of concepts and classes from other ISO TC211 standards. Most of the classes of LADM inherit of the abstract class VersionedObject. Besides temporal attributes, also the quality [DQ_Element] and the source [CI_ResponsibleParty, the responsible organization of a specific instance version in the database] are provided. The quality attribute has multiplicity 0…*, so the various quality aspects as modeled via DQ_Element can be represented.

DQ_Element is a class from ISO 19115:2003 Metadata. It is an abstract class with the following subclasses, as depicted in Diagram 3.16:

- DQ_Completeness,
- DQ_Thematical Accuracy,
- DQ_Temporal Accuracy,
- DQ_Positional Accuracy,
- DQ_Completeness.

The source attribute has also multiplicity 0..* and the class CI_ResponsibleParty is also from ISO 19115:2003 Metadata, see Diagram 3.17.

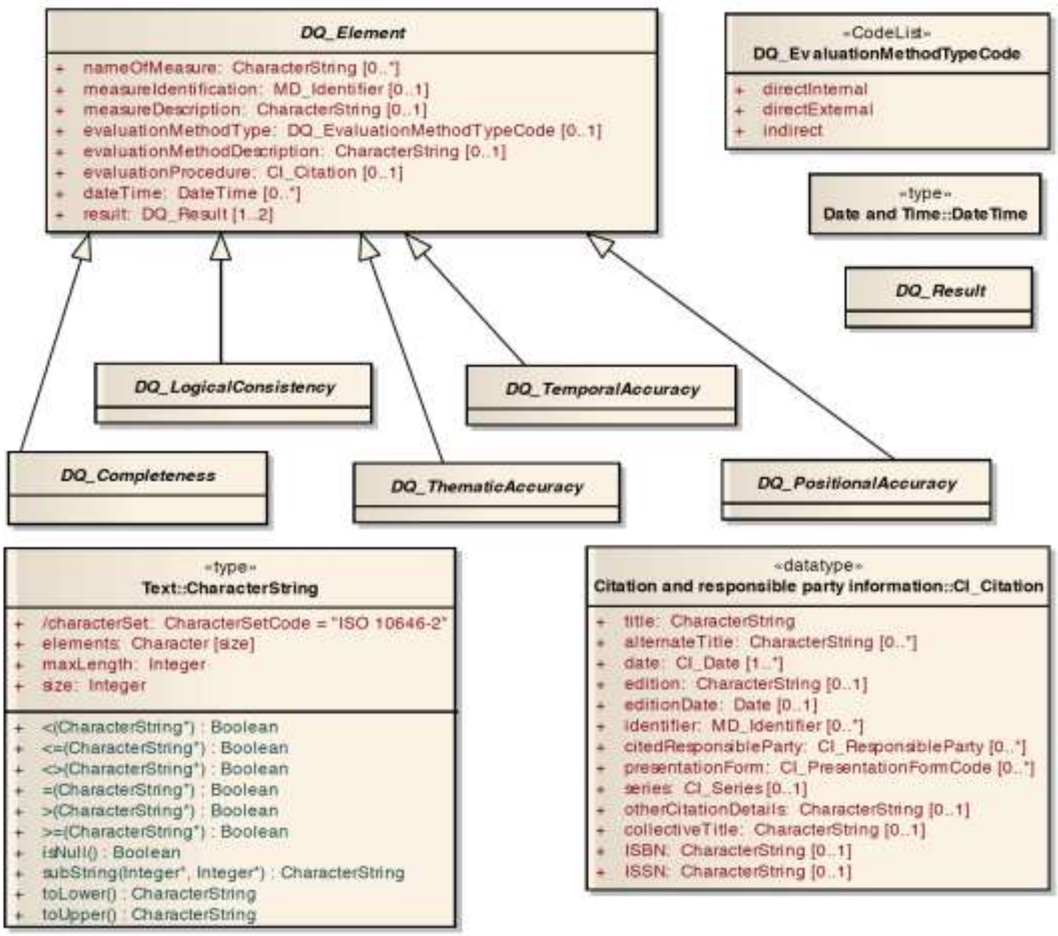


Diagram 3.16: DQ_Element class and subclasses [ISO 19115].

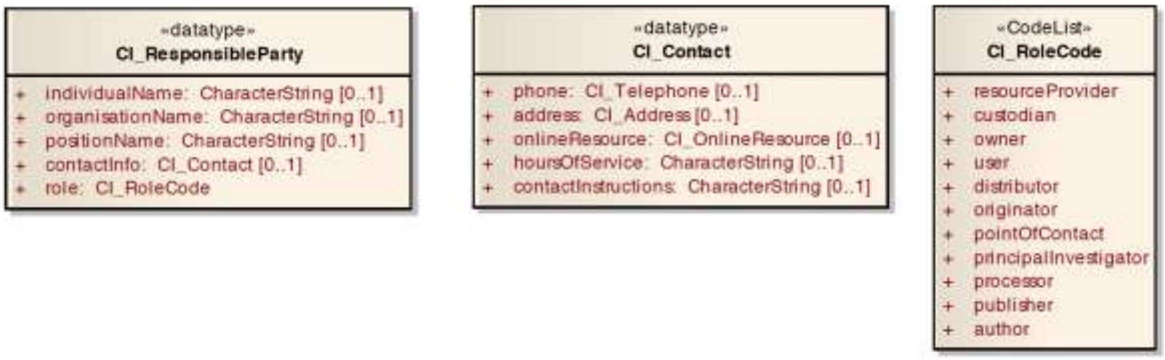


Diagram 3.17: CI_ResponsibleParty [from ISO 19115].

Another important ISO/TC211 standard used in LADM is ISO DIS 19156 on Observations and Measurements [ISO, 2011b]. It contains the actual source survey data, attributes for documenting the temporal and quality aspects of survey at the class OM_Observasion; see Diagram 3.18.

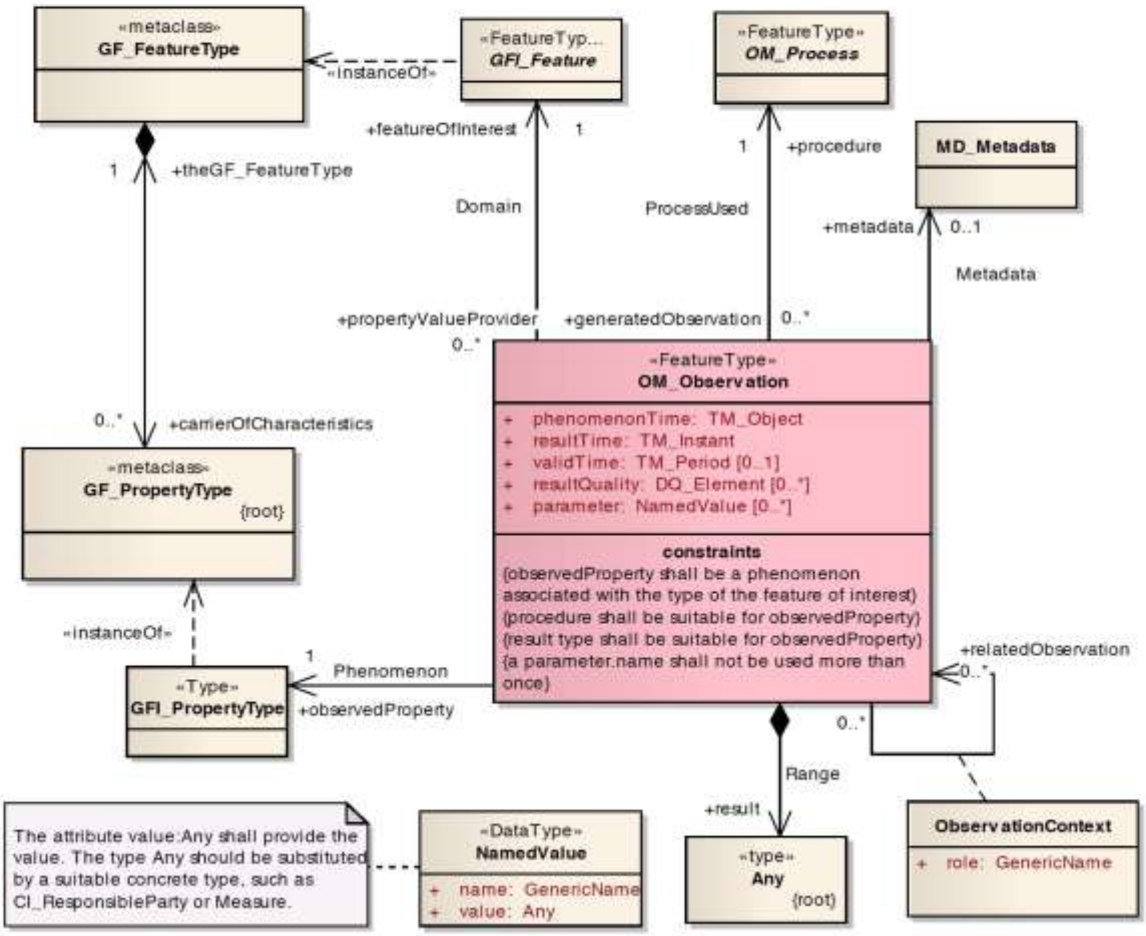


Diagram 3.18: OM_Observation from ISO19156 [ISO/TC211, 2011b].

III. Shared concepts and terminology

Despite the recent development in the filed of 3D cadastres, confusion still exists over terminology and key concepts. Terms such as 3D SDI and ubiquitous cadastre essentially refer to the same overarching concept of an information infrastructure that includes both 3D legal space and 3D representations of physical real-world objects [e.g., CityGML-like[. Meaningful communication is enabled by using existing standards where available, such as the LADM [ISO, 2012], and by further discussing terminology and concepts during international events, as proposed by Van Oosterom [2013].

Moreover, more formal semantics is asked for within the domain of 3D Cadastre. For example, an ontology should be further developed in OWL (or RDF) for 3D Land Administration [based on the foundation of ISO 19152[. This is not only need for 3D cadastre, but also in a broader sense of the whole chain of activities of 3D development, as described in 2.2.1.

Ideally, a network of ontologies/semantics should be created in a European or International level. Further formalization of the involved information, will better support the various steps and enable as much automation as possible [based on formal knowledge and reasoning]. An international/European organization should refer to conceptualizations provided by the scientific disciplines of law, economics and political science. The terminology should be well defined and values of the code lists maintained and be updated when needed.

A first step towards this direction has been made in Denmark from Stubkjær [2000].

I. Ontology for LADM

The term ontology is originated in philosophy to refer to the science of what is, i.e. the kinds and structures of objects, properties, events, processes, and relations in every area of reality [Agarwal, 2005; Mark et al., 2004]. To construct an ontology for the geographic domain, the understanding for the ontological foundations of geographic data [Soon, 2010] is crucial. Research has been done on developing the ontology for roles or user actions [Hoekstra, 2010; Mizoguchi, et al., 2012].

Ontology can be classified into Top Level, Domain and Application ontologies [Boskovic et al., 2010; Sladić et al., 2013]. Top Level ontology depicts concepts at the highest level of a domain of discourse. It includes concepts like Space, Time, Process and Event. Meanwhile, Domain Ontology describes concepts that are commonly used within a particular domain such as Land Administration. Domain ontology facilitates automation, sharing and integration of information in a domain [Van Oosterom & Zlatanova, 2008]. Lastly, Application ontology focuses on a particular application and concepts contained within this type of ontology are application specific.

Ontology is used to explicitly describe semantics by using OWL. OWL is a World Wide Web Consortium standard and a "knowledge representation language, designed to formulate, exchange and reason with knowledge about a domain of interest" [W3C OWL Working Group, 2012]. By interpreting the knowledge in the ontology, a reasoner with Description Logics [Baader et al., 2010] is able to make inference. It has three basic entities to represent knowledge; classes, properties and individuals. Classes refer to categories and properties refer to relationships or attributes. There are two types of properties: ObjectProperty and DataProperty. Moreover, classes and properties can have hierarchy. All classes, properties and individuals are called resources in OWL and each one of them has a unique Uniform Resource Identifier [URI]. An example of URI for the LADM ontology is:
http://wiki.tudelft.nl/pub/Research/ISO19152/ImplementationMaterial/LADMOntology.owl
.

The difference between OWL and UML is that OWL supports machine reasoning, while UML does not. UML uses Closed World Assumption [CWA]; which assumes that the world is complete, information that does not exist may be false; while OWL uses Open World Assumption [OWA]; which assumes that the world has incomplete information [Zedlitz et al., 2012]. The difference is that CWA treats all statements that are not false, but OWA considers missing information as undecided and new knowledge can be inferred through reasoning. Therefore, semantic web [Kolas et al., 2005] and knowledge representation follow Open World Assumption, which has the capability to reveal new knowledge; while software and database modeling supports CWA, where consistency checking is supported through constraints.

A domain ontology developed by Soon [2013] in OWL supports inference and reasoning for information integration and automation. The motivation was that user groups in land administration are huge and range from various parties and the representation of roles involves dynamics. Currently, however, roles are rather represented statically in the existing LADM model. For instance, role is considered as an attribute in the Party class, defined by the Code list. Such a definition has confined the way to model roles as context dependent.

Defining roles as a code list assumes that the conceptual structure of roles is relatively flat, however the relationships between roles themselves are much more complex. Soon [2013] developed the ontology that emphasizes user roles in Land Administration, from natural language texts using an open source ontology editor from Stanford University, Protégé 4.3.

Like in the existing LADM model, VersionedObject is also defined in the ontology as the top-level class from where all classes in the ontology are connected directly or indirectly. As a first step, the natural texts are extracted based on the definitions on the four basic classes; Party, BAUnit, RRR and SpatialUnit and then the corresponding formalization in OWL with cardinality was created. The text that follows shows an example of the Party class based on the following natural language text:

LA_Party has a specialization: LA_GroupParty [with group party as an instance[. Between LA_Party and LA_GroupParty there is an optional association class: LA_PartyMember [with party member as an instance[. A group party, being a specialization of party, is also a party. Every party, being a constituent of a group party, may then be registered as a party member of class LA_PartyMember

To develop the domain ontology, three new concepts were introduced: Role, RolePlayer and Context, together with two relations: hasRole and dependsOn. The representation of the ontology as shown in Diagram 3.19. The dashed arrow from RolePlayer to Context describes hasRole relation and the dashed arrow from Role to Context describes dependsOn relation. The rest of the arrows describe hasSubClass relation [Soon, 2013].

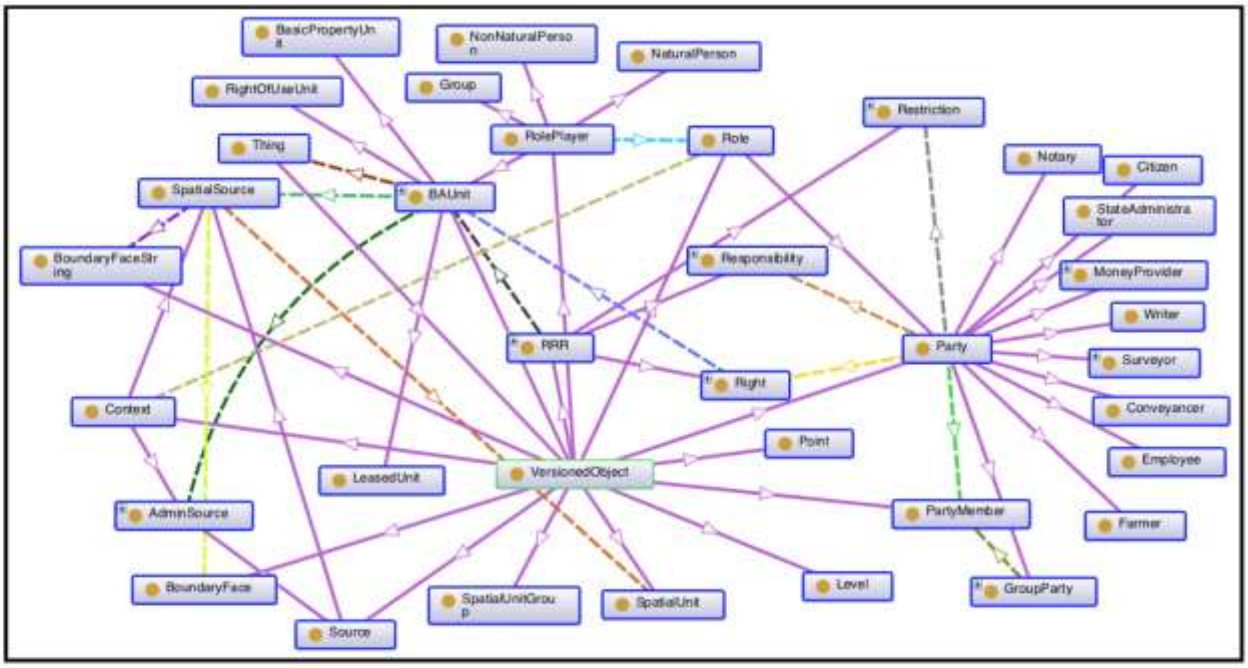


Diagram 3.19: The formalized domain ontology focused on user roles for land administration, using OntoGraf plug-in in Protégé [Soon, 2013].

This ontology attempts to support land administration systems that aim to serve customers more proactively for land administration processes. However, it is an initial step to support automation in land administration. One step further is the integration of OWL and LandXML [Soon, 2012], which combined with the use of rule language, such as SWRL and RIF is expected to raise the level of automation, mostly on the countries that have considered LandXML as a national cadastral standard, i.e. Australia and Singapore.

3.3.5. Interoperability between BIM and geospatial environments

There is a growing interest in the integration of BIM and GIS the last years and a number of publications showed promising results [Hijazi et al., 2009; IFCwiki.org 2010; Isikdag et al., 2008; Isikdag & Zlatanova, 2009b; Wu & Hsieh, 2007]. However, BIM and GIS “people” still have many differences as they use different technology, standards and syntax. The two options seen so far are in previous attempts:

- Integrating BIM data in the GIS world by using GIS technology, GIS standards and is done by ‘GIS people’ that look at buildings as information in a geospatial context.
- Modeling advanced detailed 3D buildings with high semantics. Here, buildings including streets, terrain and maybe some underground pipelines are modeled.

I. GeoBIM

Until today there is no real integration between those two “worlds”, but the majority of the geospatial community thinks that BIM and GIS word can create strong synergy [De Laat and Van Berlo, 2012]. The same authors proposed an extension of CityGML with semantic information from IFC, called GeoBIM, where a mix of strong both words is integrated in a single project.

For the creation of Geobim, firstly, the known CityGML object types like Room, Window, Door, Building, etc. are extended with extra properties from IFC [e.g. widths and heights of windows and doors]. The next level of getting IFC data into CityGML is to extent the 'AbstractBuiding' with an extra property what creates a link to the base class of our [to be introduced[extra classes, called VisibleElement. The geometry issues known in the transformation from IFC to CityGML [Nagel et al., 2009] are still not solved in this integration. De Laat and Van Berlo [2012], mention that for now the implementation in the open source BIMserver only exports IFC to CityGML LOD4, including the GeoBIM extension data. To use IFC to CityGML transformation in practice, the transformation to lower LODs is necessary. To fully integrate BIM and GIS a translation from CityGML to IFC is also necessary.

The development focuses on theoretical possibilities for the transformation of IFC data to CityGML. There is no specific use case to mirror the development. The result of the development of the GeoBIM extension [ADE[for CityGML is presented in an XML Schema file [XSD[. The result is also represented as a UML class diagram shown in Diagram 3.20. All added properties from IFC are presented in the CityGML file. The GeoBIM extension creates some new objects in CityGML; for instance a new object type is 'Stair'. This object has some properties and also has geometry.

There is increased interest for the interoperability of CAD/BIM and GIS systems, for instance, with several organizations around the world working on that such as the CAD-GIS Interoperability Working Group in the Open Geospatial Consortium and many conferences and meetings are organized in order to gather all the knowledge together; e.g. the Emerging Technology Summit [ETS]: Convergence: CAD / GIS / 3D / BIM.

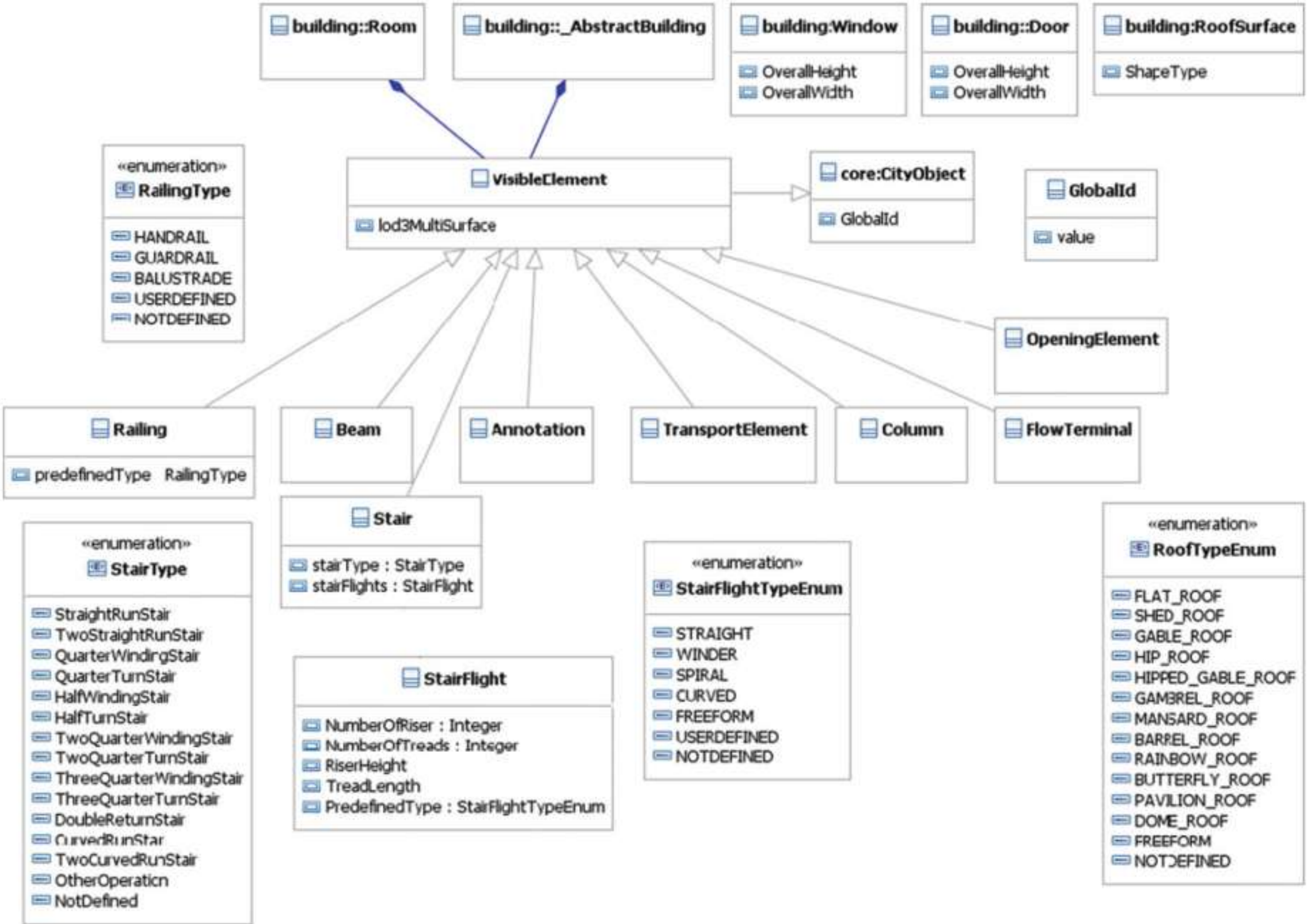


Diagram 3.20: The GeoBIM extension for CityGML.

The progress of BIM brings change to lifecycle management processes of an asset. The industry is entering Level 2 [Diagram 3.21] with many still working in CAD in two dimensions. The ultimate position is shown as OPEN BIM, where all data and systems are integrated and interoperable using the same data. The OPEN BIM moves towards the direction to establish departmental spatial capability that is fully integrated with the enterprise system. Figure 3.14 shows an example of a complete campus model where GIS and BIM/CAD technologies are integrated together with rater and legal data.

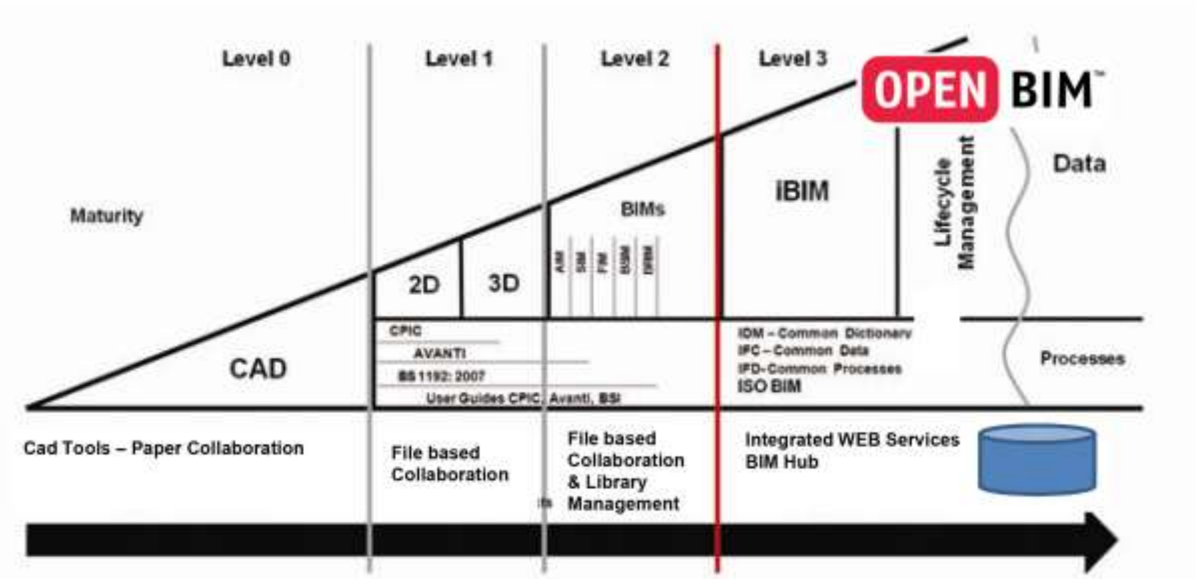


Diagram 3.21: BIM Strategy Direction [Open BIM and the future: BIM and GIS integration, 2012]

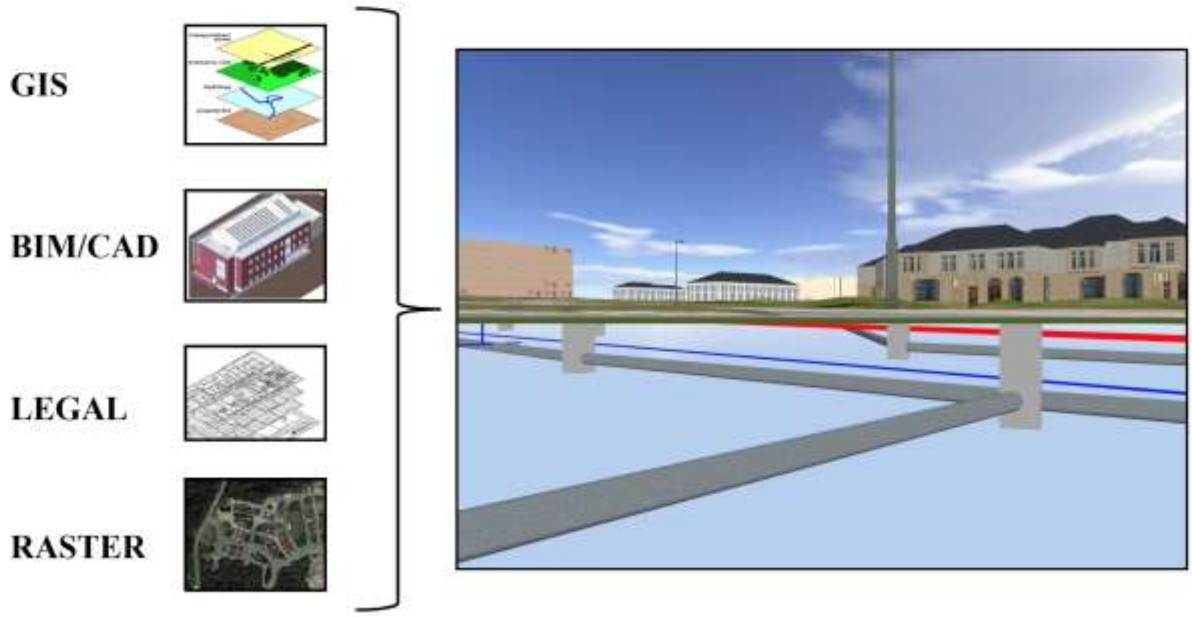


Figure 3.14: A complete ultimate model [Open BIM and the future: BIM and GIS integration, 2012]

II. Other integrations of CityGML and BIM models

CityGML and IFC models are the two prominent semantic models in the field of 3D GIS which aim at spatio - temporal coherence of spatial information. However, it is evident that they have been developed for different purposes and CityGML was not originally designed to fully comply the semantics on IFC standard. However, both are adjustable data models which enable their extension and interoperability.

Sharing and exchanging spatial information in various disciplines has been a major driving force behind the development of spatial technology and applications in the last decade (Isikdag and Zlatanova, 2009b). Nowadays, there is a growing interest in developing methods for exchanging information and bringing IFC and CityGML together.

Towards the direction of common communication standards, many approaches and prototypes and software tools have been developed in order to support various applications (urban planning, 3D cadaster, indoor and outdoor navigation, construction analysis, etc.).

As mentioned in the previous sub-chapter, GeoBIM is a CityGML ADE extension employed to obtain IFC semantic information data into a GIS framework, via a conversion process of IFC to CityGML implemented in the open source Building Information Modelserver.

De Laat and Van Berlo [2011] mention that the real integration of BIM and GIS would be at the point where the one word can learn from the other, In other words, thiw integration will be be successful when using the strong parts of BIM technology in GIS and the strong parts of GIS technology in BIM. The main part of their research is the development of a GeoBIM extension on CityGML for IFC data achieving the addition of semantic information from IFC into CityGML.

The authors conclude that the transformation of IFC semantics into CityGML has shown promising remarks, however in order to fully integrate IFC and GIS research and implementation of prototypes should be done in central model servers.

At a recent research, El-Mekawy et al. [2012a] and El-Mekawy et al. [2012b] address the need for combining IFC model with CityGML and propose a unified model which is defined as a superset model concept containing the features from both IFC and CItyGML models, while omitting their relationships. This approach shows promising results as the Unified Building Model [UBM] can be the common ground whereIFC nad CityGML models can be smoothly integrated without any need for conversion [Figure 3.12].

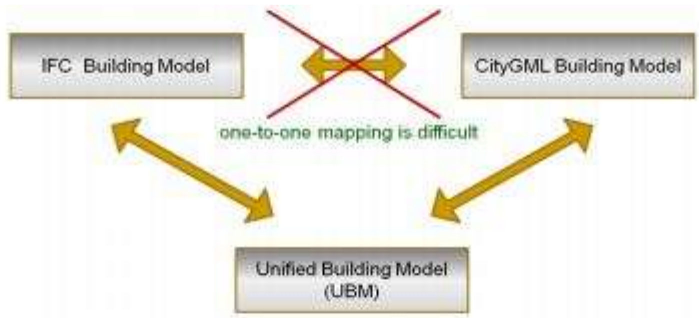


Figure 3.15 : The UBM as meta-model [El-Mekawy et al., 2012a]

An implementation of UBM in ArcGIS is presented in Figure 3.13, which depicts part of a perspective model representing an IFC building (right side), and a combination of a CityGML building (left side), and its CityGML surrounding environment El-Mekawy et al. [2012b].

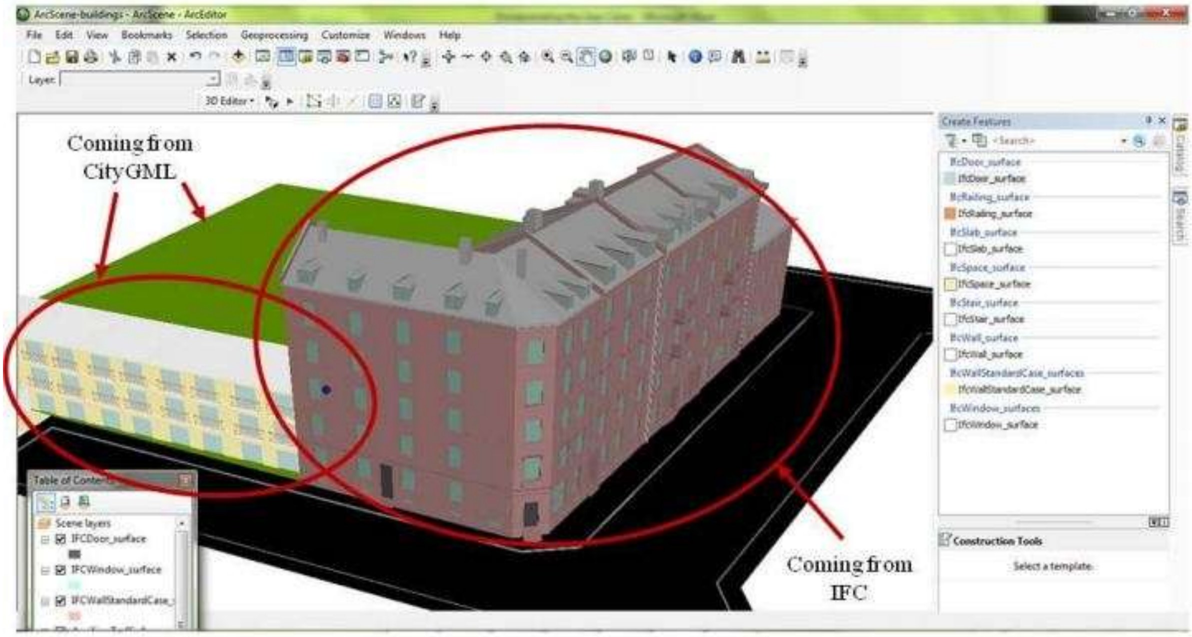


Figure 3.16: UBM representation of IFC and CityGML data integrated, El-Mekawy et al. [2012b].

The need for the integration of the two models is nicely presented by El-Mekawy et al. [2012a] at the following diagram. Nowadays, multiple initiatives have been developed (e.g. INSPIRE Directive, etc), which suggest the creation of common spatial applications and they require the integration or, at least, the communication, among the existing standards for spatial information.

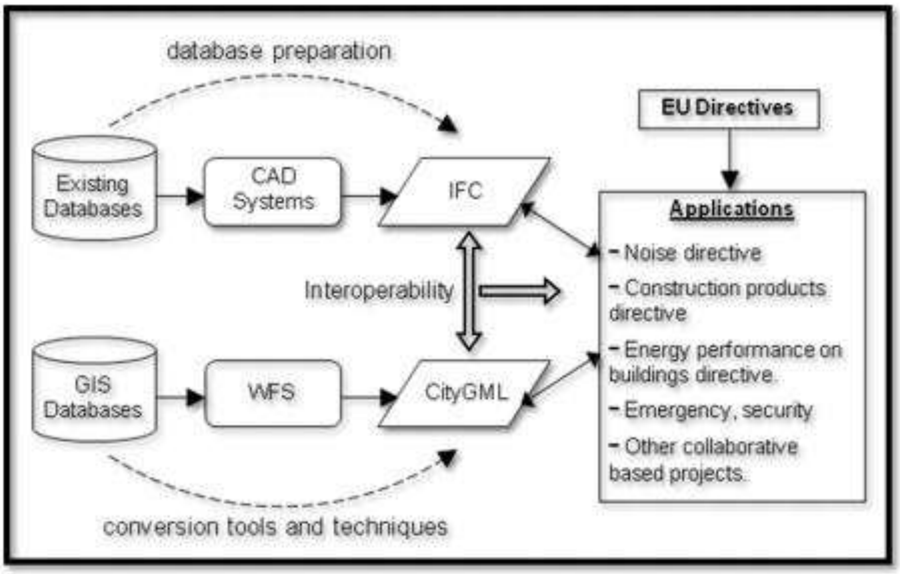


Figure 3.17: Proposed integration approach for CityGML and IFC integration, El-Mekawy et al. [2012b].

Additionally, International Alliance for Interoperability [IAI] advancing BIM work based on the Industry Foundation Class [IFC] standard, and eXtensible Markup Language [XML[and XML-based GML expressions of IFC are being developed to improve the integration of geospatial as well as architecture, engineering, construction and facilities management [A/E/C/FM[information in a single model.

Generally speaking, there is need to integrate the "GEO" aspect [geoinformation] with BIM, towards the concept of smart cities. 3D Cadastre is an example of Geo-BIM, as shown in Figure 3.18 from Stoter's presentation at the same event [Stoter, 2014].

This challenge was introduced in Geo-BIM - Smart Infrastructure event in Amsterdam [http://www.geo-bim.org/europe/speaker.htm].

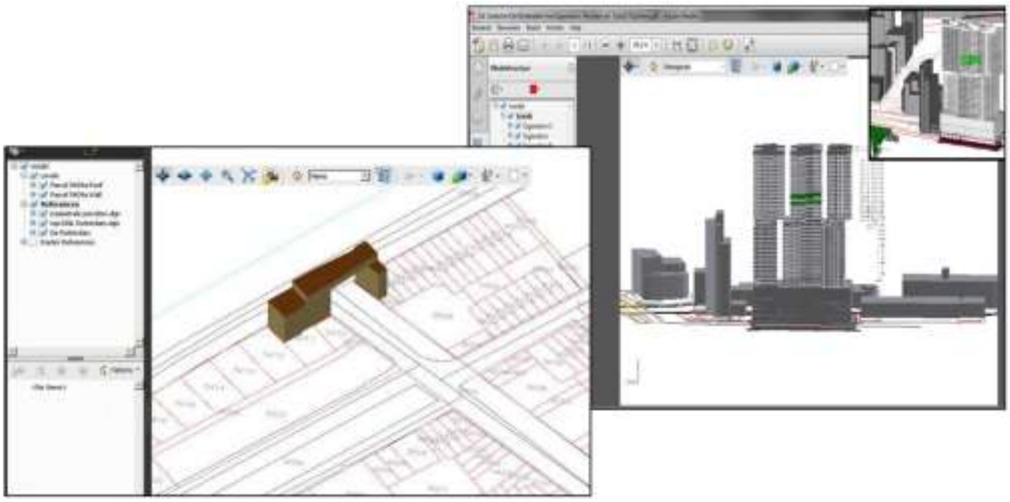


Figure 3.18: 3D Cadastre, an example of Geo-BIM [Stoter, 2014].

3.4. Conclusions

Nowadays, most countries have developed their own land administration system; which serves the country's needs. Those LASs are not always based on an international standard; which creates many problems mostly on the compatibility and interoperability of the responsible organizations both inside and outside of the country. Although the approaches concerning 2D and 3D properties in each country differ, they share similar principles that can be found. Standards are based on those similarities.

Standardization is defined as the development of agreements and rules amongst users to create unity and clarity where diversity is unwanted. Standards and communication protocols are key concepts towards this direction. In this chapter, some of the most important models for land administration are presented together with standards for storage and exchange of geo-information, in the context of 3D cadastres.

Nowadays, multiple standardization organizations propose many different standards to support different activities. They can be de juro standards or de facto [2], open or proprietary. Standards for conceptual models, technical standards and specifications as well as communication protocols have been introduced in order to enable, facilitate and improve the maintenance and exchange of geographical information between different organizations in the same country or from different countries.

According to Van Loenen [2014], standards represent an effective way of transmitting information facilitating co-ordination and communication and promoting compatibility. They reduce the complexity resulting in simplicity of the processed they refer to. The aim of standardization is to adapt a world of increasing interdependences with a comparative advantage.

Additionally, the importance of SDI increased over the last years. SDIs became very important due to the rapid improvements in spatial data collection and communication technologies. The recent explosion in the amount of spatial data calls for better organization, management and analysis, specialized systems and use of standards for spatial types and spatial operations and there the SDI comes into account. To benefit from this data and use it for decision-making and planning, data should be available and assessable for the responsible authorities and therefore many countries have developed their NSDI.

In this chapter significant standards in the domain of geo-information and land administration were described and their interoperability was discussed. The main purpose of standards is to facilitate interoperability and data exchange, which means that they should be compatible.

"*The nice thing about standards is that you have so many to choose from*."

[Andrew S. Tanenbaum]

[2] **De jure standards**: standard published by an official institution/ legal obligation to use the standard

De facto standards: in practice a standard; a custom, convention, product, or system that has achieved a dominant position by public acceptance or market forces [e.g., QWERTY, PDF, etc]

4. 3D Cadastres/3D LADM: International Experience

Recent works suggest that the utilization of LADM international standard for cadastral domain is significant as mentioned by several researchers: Lemmen [2012] Van Oosterom et al [2011], Pouliot [2011], Hespanha [2012] and Ary Sucaya [2009]. Many countries such as Poland, Republic of Korea Malaysia, Indonesia, Croatia, etc. have proposed country profiles based on LADM as reported by Bydlosz [2013], Kim et al [2013], Budisusanto et al., 2013 and Vucic et al [2013]. There is no reason to refer to all of the existing profiles here. For that reason, a selection was made according to the most recent profiles, which make use of the latest technological advancements and also have common aspects with the Greek proposed LADM model, and they are presented in this chapter.

The first LADM country profile presented here is the one of the Russian Federation. As a conceptual model it is not very different from the classes of ISO 1952, however it explores the possibilities to use LADM as a reference model in a 3D Cadastre. At the same time a "Russian-Dutch Project: 3D Cadastre Modeling in Russia" was conducted aiming to evaluate the possibilities for better reflecting the real world through a 3D Cadastre. It focuses more on implementation of a prototype trying to solve the problem of multilevel complexes and underground and elevated objects. It is considered as very technical proposal with a useful and interactive interface.

The proposed LADM profile of Malaysia is chosen to be presented here for the following reasons: a lot of work and research have been conducted the last two years for the creation of a model compliant with LADM and based on the existing Malaysian model; 2D and 3D geometries are integrated in the proposed model; the concept of levels as groups of spatial units with thematic or geometric coherence is used as well as a prototype is created for the creation of a technical model derived from the conceptual schema using the latest technological developments, the implementation of the conceptual model in a database and querying in 2D or 3D the database using an interface to visualize the result.

Another reason for referring to the Malaysia LADM country profile is that some important aspects during the whole process of the prototype development are considered to be used for the Greek LADM country profile. In particular, the proposed model [6.4] also uses the concept of levels in order to better manage the different types of spatial units in the country and also is expected that in future this work will be continued in order to develop a prototype for the proposed Greek LADM profile.

On the other hand, the LADM profile of Israel is mentioned because Israel was one of the first countries towards the exploration of 3D Cadastre solutions, involve multiple organization for the exchange, storage and distribution of the information and also uses the 3D sub-parcel principle. Additionally, the country profile is extended to the third dimension and also makes use of current technologies for 3D modeling. Therefore, it is considered as one of the most recent, complex and successful examples.

4.1. The Russian Federation

Aiming to introduce 3D cadastre registration in the Russian Federation, the Russian Government commissioned 3D cadastre modeling project. After the initial analysis of the Russian legislation, an inventory of possible use cases in Russia, and the examination of 3D Cadastre 'solutions' in other countries, the project is currently in the phase of the design of a 3D Cadastral model, which will then be followed by the development of a prototype system. The project is based on experience of the Netherlands [Stoter, 2004; Stoter and Van Oosterom, 2005] and other countries [Van Oosterom et al, 2011].

There are multiple Russian and Dutch partners in this project. Van Oosterom et al., 2012 analysis showed that the cadastral law in the Russian Federation is quite generic concerning 3D situations: it neither explicitly mentions 3D, nor does it prohibit 3D volumetric parcels for registration. However, the Russian Federation has a strong drive towards a 3D cadastre for better registration of complex buildings, or other types of constructions, and subsurface networks [e.g., cables and pipelines].

The current cadastral parcel registration system is 2D polygon-based, in the terminology of the LADM. The database contains the full history of the parcel since its creation. The Russian Cadastre registers more than land parcels and depending of the area, urban or rural, in different scales. In particular, the Russian cadastre registers five types of objects:

- Land [parcels],
- Buildings,
- Apartment Units,
- Other structures [bridges, pipelines etc.] and
- Unfinished objects, i.e. objects under construction [buildings, bridges, pipelines, etc.].

The implementation of this model, both the administrative and spatial parts, is realized via the two existing databases of Rosreestr [the responsible organization for the Cadastre]: the 'Cadastre' database and 'Registration' database.

The design of the 3D Cadastral model is based on an analysis [of the geometric part] of the current Cadastre registration. As a reference model the ISO 19152, LADM has been used]

Diagram 4.1]. This already includes a 3D spatial profile.

Based on the requirements derived from the potential use cases, it was decided that the 3D registration is based on two objects: 3D polyhedron volume [flat planes] or 3D multicurve with diameter [curved surfaces around pipelines]. A topologically structured 3D Cadastre, is not conform the current 2D Russian Land Registry, which has no topology.

The motivations in favor of the selected approach are that this approach is in line with the existing 2D registration and should be relative easy to implement. The 3D volume parcels have their own geometry, similar as in the current 2D database (via polygons). However, the geometry is represented by a polyhedron (volume bounded by flat faces) or multicurve with diameter. Consequently, the advantages are clear: relatively easy implementable with current technology (database, GIS/CAD), and similar to polygon approach in 2D. A drawback is that it does not support a topology structure [for better quality guarantees] and no curved faces. This means that during data entry careful checks have to be implemented to validate that 3D volume parcels are well formed and non-overlapping. Because curved faces are not supported (except via multicurves with diameters for pipelines and cables), curved boundary surfaces need to be approximated by a series of flat surfaces. This is not a serious limitation and quite a practical and easy to implement solution.

The model is used for the specification of the rules for the initial registration of 3D parcels, for the extended database schema, and for the dissemination and visualization of the 3D parcels in combination with the existing 2D parcels.

The technical model requires to develop guidelines describing how in the future in Russia, 3D parcels must be submitted for registration. These guidelines are based on experiences in other countries; especially the Queensland 'Directions for the Preparation of Plans'. Chapter 10 of these directions describes exactly how a volumetric parcel should be described so it can be registered. Based on this example and after analyzing the Cadastre in the Russian Federation, the guidelines are defined for the registration of new 3D parcels/cadastral objects [Vandysheva et al, 2011].

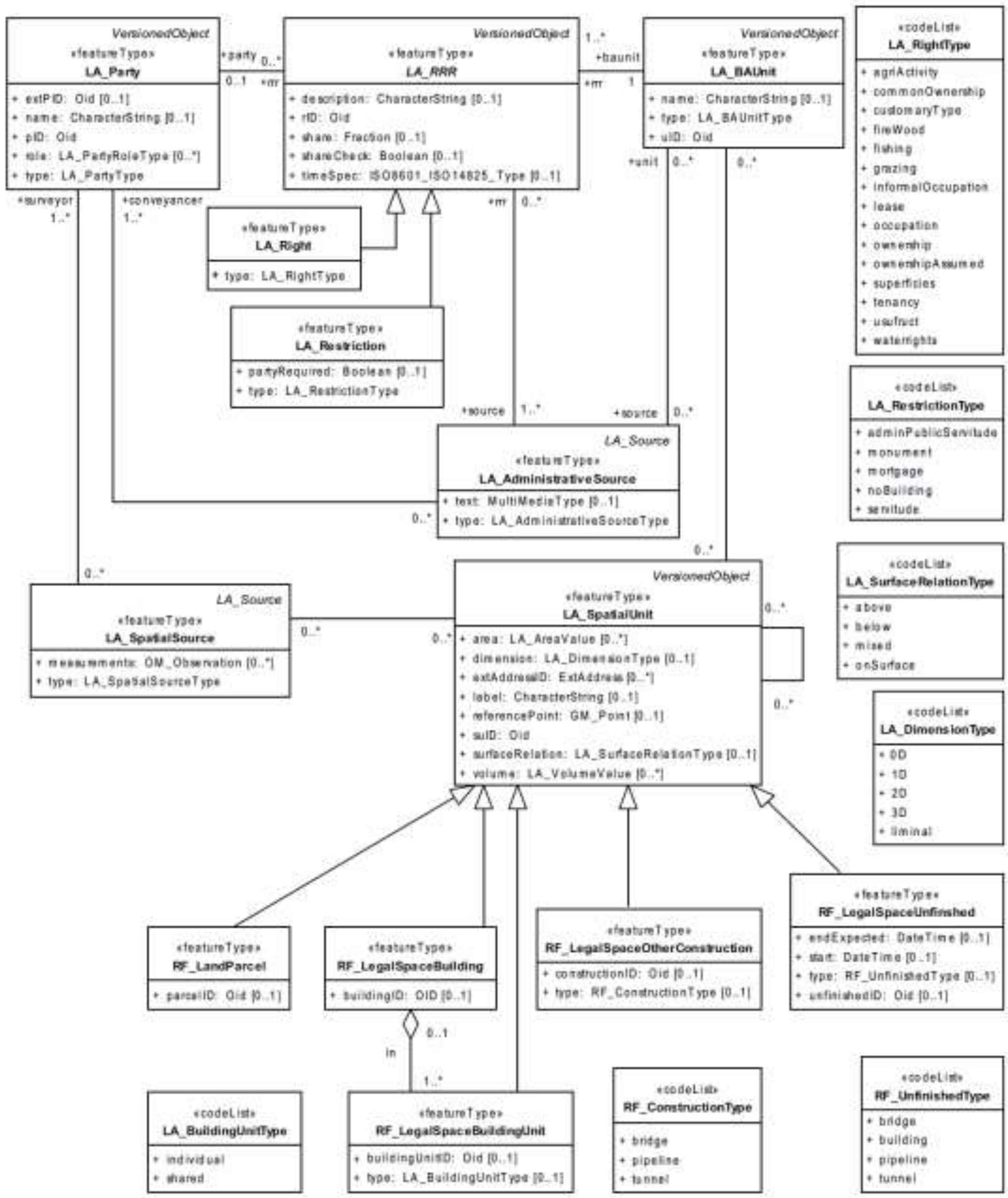


Diagram 4.1: LADM profile of the Russian Federation [ISO 19152, 2012].

The preference is to store the 3D parcels in the same database table as the 2D parcels, so no database schema change is needed. However, an alternative option would be to introduce a new table for these 3D objects. It is possible to derive from the 3D geometry the 2D contour of intersection of 3D object with the surface z=0 and the 2D projection contour of the 3D object on the surface z=0. These 2D contours (polygons) do not have to be submitted as they can be computed. So, it is possible to store these derived 2D polygons together with the 3D polyhedron. It has to be decided whether these are computed on the fly or stored explicitly. The new 3D parcels have to be validated against the existing area's (2D parcels) and 3D objects: are the rights properly transferred.

There are different options to store the 3D data:

- **Documents in 3D PDF:** the advantage is that both legal text and drawing can be integrated into one document and then submitted. However it is not possible to directly extract the 3D geometry.
- **3D data in XML:** the actual encoding of a 3D parcel will be done in the XML based on the integration of LADM-3D and CityGML. This enables explicit link between the legal parts of a 3D Cadastre with its physical counterpart.
- **3D data in the Oracle Database**: in the administrative part of the existing database schema there are no changes at all. Because of the use of polyhedron-based objects there are also not many changes at the geometric part.

In order to test the prototype several use cases where used. Figure 4.1 illustrates one of those. Besides 2D cadastral parcels and related administrative (legal) information, each case also includes terrain elevation, reference topographic data and 3D. Here, a short underground gas pipeline of low pressure is presented. The pipeline crosses a land parcel, on which complex of museum buildings are located. Pipeline got two exits on surface (hatches), for which two (very small and hardly visible in the Figure) land parcels are allotted land parcel 2 and land parcel 3.

Figure 4.1: At the top the cadastral map fragment including the pipeline and at the bottom two different 3D views are depicted [Van Oosterom et al., 2012].

After completion this prototype can be used to illustrate and test the possible future workflow around 3D parcels in Russia: accepting newly registered 3D parcels, and correctly storing them into the database for possible future access.

4.2. Malaysia

The Malaysian land administration system is based on the Torrens system. The main objective of the Torrens title system is to make the register of documents of title conclusive evidence of land ownership. Once a person's title or interest is registered in accordance with the prescribed registration procedures, it will be recorded in the register document of title, and the person in whose favor the dealing is registered will become the indefeasible proprietor or interest holder to the exclusion of all others. The current cadastral system in Malaysia is still not able to answer several 3D situations as proposed by Stoter o2004], Thomson and van Oosterom [2010] as the 2D cadastre still plays a dominant role in the land administration.

During the last couple of years, the potential of 3D and LADM based cadastral registration in Malaysia has been investigated and described in several papers, [Abdul Rahman et al, 2011, Tan and Looi, 2013, Zulkifli et al, 2013]. All this research has resulted in a proposal comprehensive LADM country profile supporting 2D and 3D cadastral registrations in Malaysia and in a prototype, which will be used for the implementation of the conceptual model. The prototype has limited functionality, as the main purpose is to access the conceptual model and derive the technical model; it will not address multi-users aspect or develop a Web-based interface for dissemination.

To start with, in Malaysia there are two organizations responsible for managing and maintaining the cadastral system with different responsibilities. The Malaysian land consists of multiple types of spatial units. Additionally, the concept of sub-division of a building into parcels together with numerous other amendments was introduced in the country at the early 70's and since then the Strata Titles Act enacts. Figure 4.2 illustrates the various types of cadastral objects related to Strata Titles within a lot.

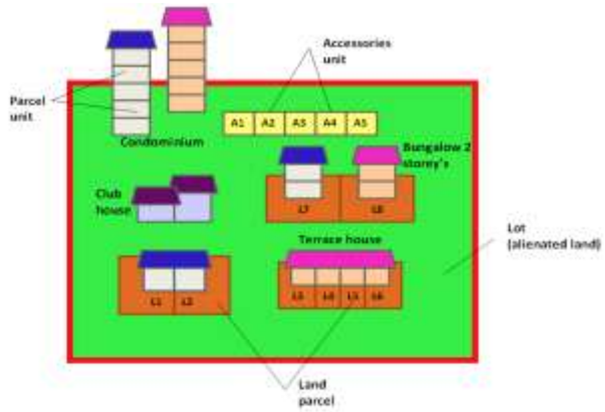


Figure 4.2: Various cadastral objects related to strata tiles within a lot [Zulkifli et al., 2014].

As mentioned before, based on earlier work the Malaysian country profile is now based on inheriting from LADM classes, "MY_" is the prefix for the Malaysian country profile. The administrative part is adopted from the LADM standard [the classes are directly inherited by LADM and that is why they are not presented here], the spatial part contains various refinements and 3D geometric descriptions.

Diagram 4.2 Illustrates the proposed spatial profile based on LADM. In the proposed country profile spatial units can be 2D or 3D. The model has introduced an abstract class MY_GenericLot holding the attributes of a lot and this class has two specializations MY_Lot2D and MY_Lot3D, with their own attributes and structure. Currently MY_Lot2D is based on 2D topology with references to shared boundaries [MY_BoundaryFaceString]. In the 3D case, topology is not used: not for lots [MY_Lot3D], nor for strata objects.

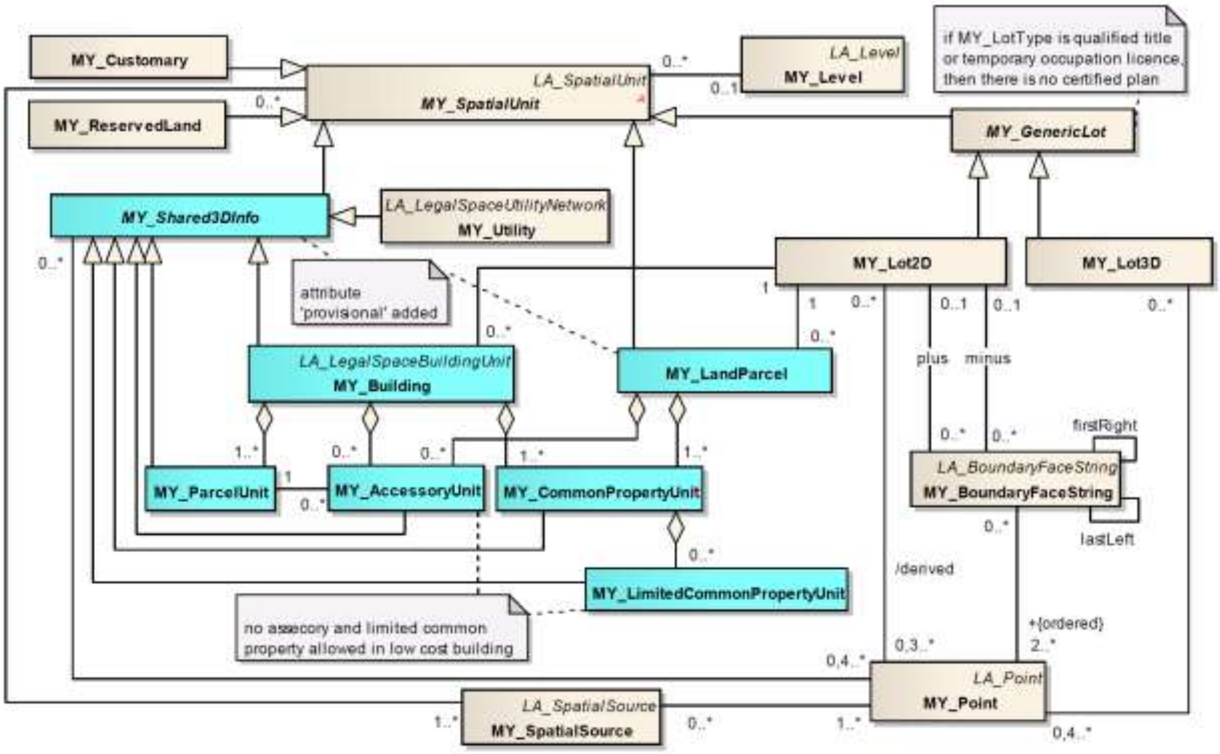


Diagram 4.2: Overview of the spatial part of the Malaysian LADM country profile; blue is used for strata titles related classes (Zulkifl et al., 2014).

In the model one strata object type remains to be represented in 2D, MY_LandParcel (with building no more than 4 storeys). The other strata objects are all proposed to be 3D and therefore inherit form an abstract class MY_Shared3DInfo, with strata specializations (and mutual aggregation relationship): MY_BuildingUnit, MY_ParcelUnit, MY_AccessoryUnit, MY_CommonPropertyUnit, and MY_LimitedCommonPropertyUnit. As there can be several LimitedCommonProperty's in one CommonProperty, this is modeled as a part-of relationship to MY_CommonProperty (the aggregation class).

To make the model comprehensive and future proof, a wide range of spatial units can be supported including legal spaces for utilities (3D), customary areas, and reserved land (forest, wildlife areas). The various types of spatial units are organized in levels using the class MY_Level. For this class there is an attribute type that described level type of the spatial unit, which will include: customary, lots, buildings and utilities. The code list for these attributes can refer to MY_LevelContentType.

According to ISO 19152, 2012, LA_Level and therefore, MY_Level is a collection of spatial units with a geometric or thematic coherence. For Malaysia the following levels are proposed: level 0 for customary, level 1 for reserved land, level 2 fir 2D lot, level 3 for 3D lot, level 4 for strata and level 5 for utility.

In Malaysia standard codes for features and attribute code exist according to law. Newly proposed code list for the non-spatial and spatial packages have been proposed, see more in Zulkifli et al., 2014.

After the creation of the conceptual schema the first step of the prototype development was the conversion of the conceptual schema into a technical model; the target is a database schema (in Oracle Spatial). A class in the UML model normally corresponds to table with same name in the database schema. Additionally, there are also views, tables for code lists and additional tables for representing relationships in case of a many-to-many relation between two classes.

There are many types of constraints e.g. the primary key must be unique, endDateTime > beginDateTime, end date of previous version must be equal to start of next version, sum of shares must equal to 1, boundary of lot must be closed, boundaries may not intersect, etc that need to be implemented in the database. There are several issues concerning the creation of the technical model in the database such as the use if views, clustering and indexing and the topological structure that are analyzed in Zulkifli et al., 2014 prototype.

Additionally, some sample data are converted into the model in order to test the efficiency of the database. After creating the database schema and loading sample data, the prototype frontend development is based on Bentley Microstation [Figure 4.3]. Using this application, queries are conducted via the visual SQL Query Builder. In general, the prototype development consists of four steps as depicted in the next figure.

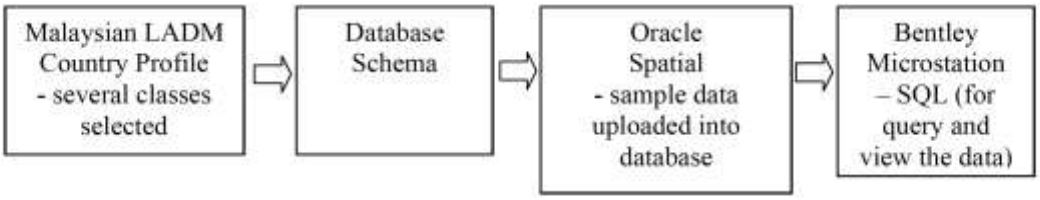


Diagram 4.3: the four steps of the prototype development [Zulkifli et al., 2014].

The current prototype only covers 2D lots and 3D strata objects and the remainder of the classes will be dealt with at later development stage. The outlook of this research is as follows, realization of a near future prototype that covers all functionalities with large area, development of regulations for digital certified plans with 3D objects, redesign XML exchange formats for LADM based on Malaysian data, and creating prototype with appropriate web interface for land office data accessibility.

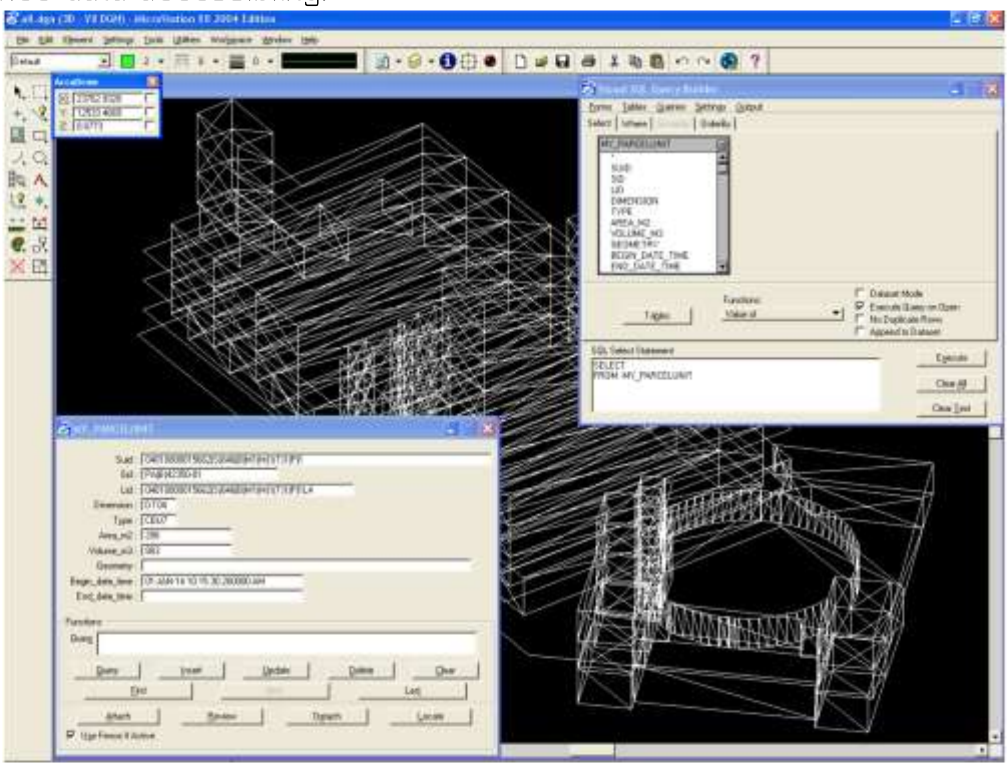


Figure 4.3: 3D data query and visualization of MY_ParcelUnit using Bentley Microstation [Zulkifli et al., 2014].

4.3. Israel

Israel is a relatively small country, with a rapidly growing population, the pressure on the available land/space is increasing, and today's technology is enabling 3D functionality It was among the first countries in the world to address the topic of 3D representations in the cadastral registration [Benhamu and Doytsher 2001, Forrai and Kirschner 2001, Sandberg 2001 and Sandberg 2003]. This was facilitated by a two year 3D Cadastre project during the years 2002-2004 [Shoshani, Benhamu,Goshen, Denekamp and Bar 2004, Shoshani, Benhamu, Goshen, Denekamp and Bar 2005,Benhamu 2006] when it was proposed for the first time a solution to 3D Cadastre by sub-dividing the surface space into spatial sub-parcels. The early R&D in Israel was not directly transformed in an operational system due to legal, organizational and technical aspects. Despite the fact that the 3D representation was not yet introduced to the Israeli registration, the 3D research that have been conducted to many topics puts Israel in a high knowledge level.

In this sub-chapter, the development of the LADM country profile is presented, which is a joint activity involving the Survey of Israel, the Land Registry, Israel Land Authority [93% of the land in Israel is in the public domain, and ILA is responsible for managing this land], and the licensed surveyors [creating the new 2D and 3D parcel representations[. This is one of the reasons this LADM profile was selected to be mentioned here as there are many different organizations involved and strong cooperation is needed. The cooperation is not only needed for creating the Israeli LADM country profile, but also to agree on new functionality as well as for data exchange, data synchronization and joint data delivery.

As Israel has already explored possibilities and difficulties of 3D Cadastre for quite a long time, requirements were set of which the main two aspects are [Shoshani, Benhamu, Goshen, Denekamp and Bar 2005]:

- Prepare appropriate legislation framework and,
- Solve the problems derived for a 3D Cadastre from the 3D sub-parcel principle.

The 3D sub-parcel concept is based on subdivision of the unlimited column of space implied by the 2D surface parcel into at least one completely bounded 3D volume and a remaining (unlimited) space. The bounded 3D volume is within the column of the 2D surface parcel [Felus et al., 2014], see Figure 4.4.

The logic behind the sub-parcel is the following: the owner of the surface parcel (3D column of space) splits the owned space and sells one part to another party. For long infrastructure type of objects the result is that one object, such as a tunnel, is to be represented with many 3D sub-parcels.

To each of the 3D sub-parcels the same right and party should be attached, both initially, but also in future transactions (e.g. tunnel is sold to a company). This is redundant information and error prone. After a lot of research it is conclude that it is better to allow 3D parcels crossing many surface parcels. It has recently been decided that whilst being a necessary stage in the process of creating a new 3D parcel, it will not be the final stage. Within a cadastral block the temporal sub-parcels are merged into a single larger and connected 3D parcel with same right and party information attached.

Moreover, concerning the legal aspects a more in-depth analysis was conducted for the existing legal tools and concluded that the preferred solution is to establish specific legislation for creating spatial parcels. Similar to the scoping questions raised by the FIG Working group 3D Cadastres [van Oosterom, et al, 2011].

Israel, as any other country, has to consider where, when, and how to apply 3D Cadastre. It may be wise to design a more generic solution, from legal, organizational and technical points of view, of which initially only the most urgent cases will be represented in 3D. However, it is to be expected that in less urgent cases the needs or expectations of society in the future may also change and it is wise to anticipate or even stimulate these future uses of 3D registration [Felus et al., 2014].

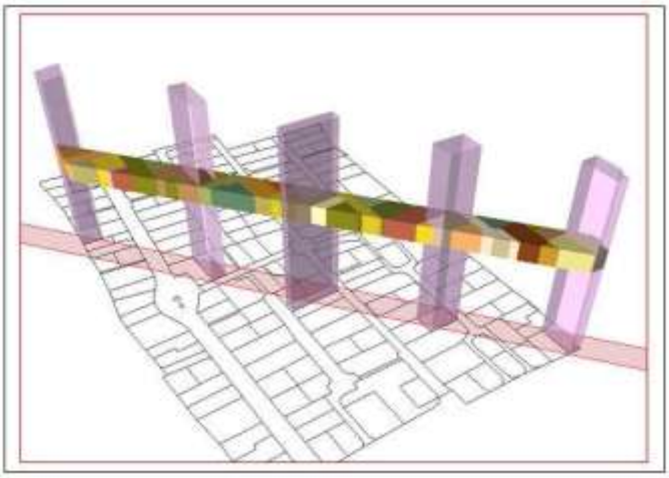


Figure 4.4: 3D presentation of the spatial sub-parcels on the background of existing land parcels [Shoshani et al., 2005]

The Israeli country profile both considers the current registration (in 2D) and the wishes for the future registration. Therefore the first step is analyzing the key concepts in LADM and their counterparts in the actual registrations and link related concepts. Diagram 4.5 shows a UML diagram of the current registration in the initial Israeli country profile as specialization of LADM. The prefix 'IL_' is used to indicate the fact that this is the Israel country profile. The following inheritance relationships are shown IL_Parcel (from LA_SpatialUnit), IL_ParcelArc (from LA_BoundaryFaceString), IL_ParcelNode (from LA_Point), IL_Gush (from LA_SpatialUnitGroup), and IL_Talar (from LA_SpatialSource).

The first step towards 3D parcels is the introduction of the 3D IL_BoundaryFace (from LA_BoundaryFace), but this needs to be further developed. The same is true for the administrative side of the Israeli LADM country profile.

A cadastral registration with 3D support has impact on the complete process: from data acquisition until data dissemination in 3D and all steps in between. Diagram 4.4 shows the seven steps in this workflow.

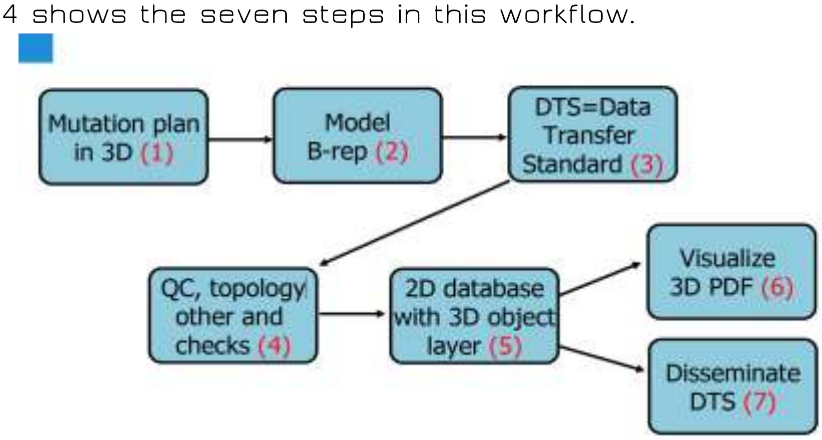


Diagram 4.4: The 3D cadastre workflow in Israel [Felus et al., 2014].

The process begins by providing the spatial data sources of the new 3D parcels. Today, new buildings are often directly designed in 3D and with some limited additional effort it should be possible to create the relevant 3D cadastral objects. With respect to step 3 the DTS has a range of options: LandXML or

InfrGML, BIM/IFC, other prototypes, etc. The next step covers the automated quality control in 3D for topological and geometrical errors. After that, the 3D parcels have to be stores in the database, be visualized and disseminated either through web or desktop.

Additionally, there are different ways to model 3D parcels in LADM. It gives the opportunity to extend the existing 2D database with 3D LA_Level. For instance, the parcel 2D records (base properties) will be linked with these exclusions/ additions (see Figure 4.5). In order to define a parcel which is open on the side of top and/or bottom and bounded on the other sides the LA_Level approach with a 2D parcel level and a 3D parcel level is followed:

- o have 3 parcels (A, B, C) in 2D parcel level, implying 3D columns;
- o have 1 parcel (A-1+B-1) in 3D parcel level; and
- o use LA_BAUnit to combine C with A-1+B-1.

Then the parcels A and B, both 3D columns, have exclusion (A-1+B-1) via the LA_Level approach. Parcel C has documented extension via LA_BAUnit grouping.

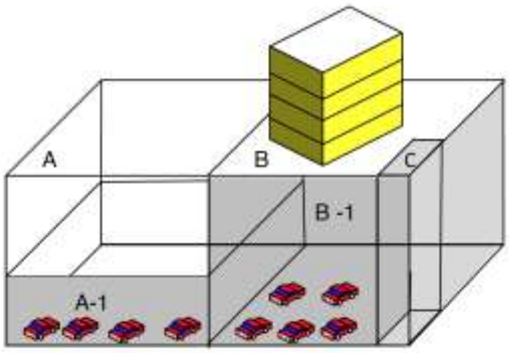


Figure 4.5: The parking lot parcel is composed out of the shaft parcel (C) which is infinite parcel A-1 which is the exclusion from parcel A and B-1 which is the exclusion from B Felus et al., 2014).

After developing the Israeli LADM country profile, still many technical design and implementation decisions have to be made during the conversion of country profile to technical model: identifiers (PK, FK), time stamps, versioning, indexing, clustering, multiplicity of attributes and relationships, constraints, derived attributes and the earlier mentioned 2D/3D geometry/topology structure. Israel supports that this is a national activity with the co-operation of many different organizations.

The fundamental question arises should these 3D space, time and scale 'attributes' be treaded separately, or is it worthwhile to deeply integrate these in a single higher dimensional representation as suggested in (van Oosterom and Stoter, 2010). These topics are related to the recently started research "5D Cadastral GIS project (5DMpLIS - 5D Cadastre GIS)" by an Israel-Greek consortium.

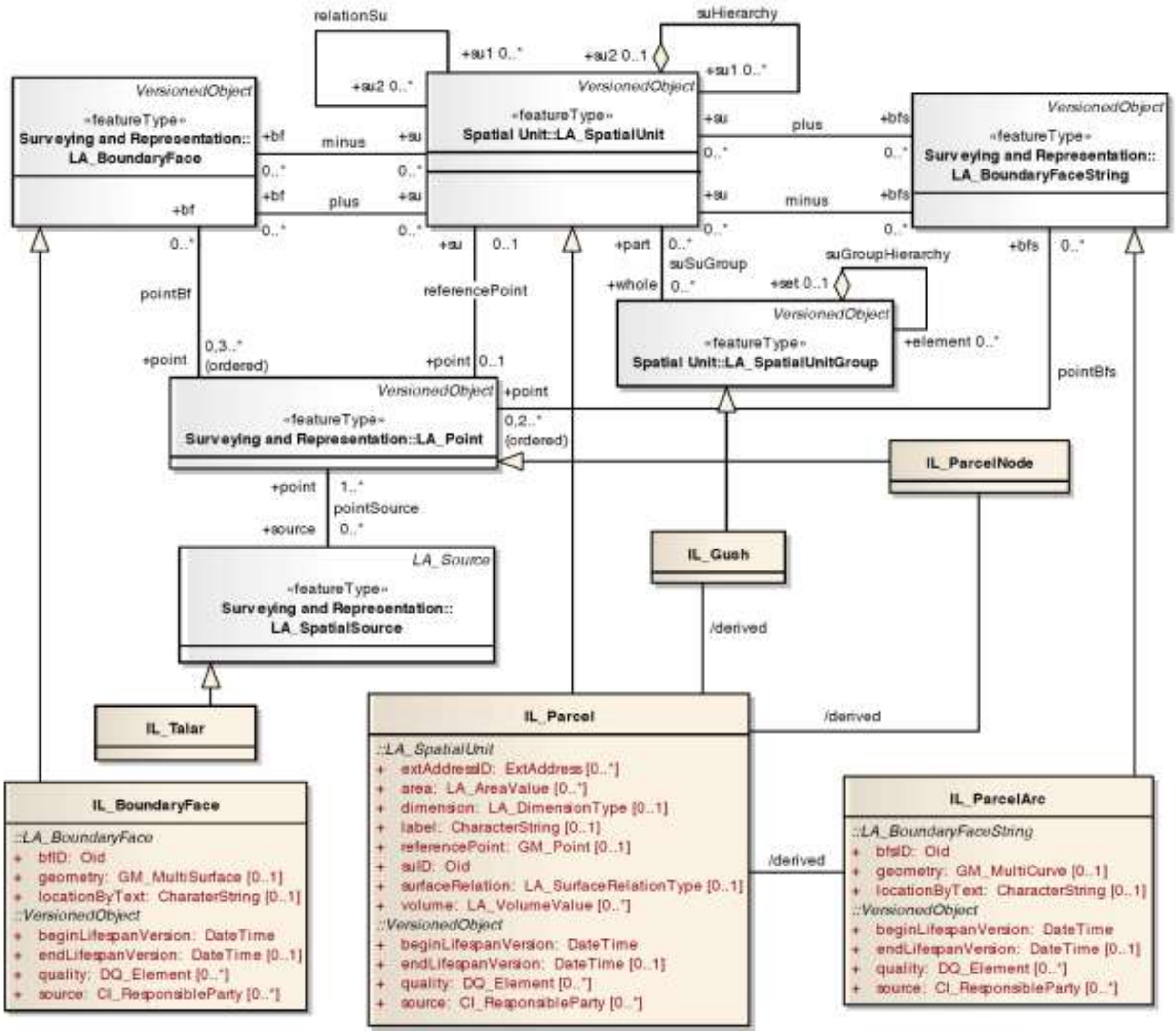


Diagram 4.5: Current situation of the spatial part of land administration in Israel, UML model of the initial Israeli country profile as specialization of LADM [Felus et al., 2014].

4.4. Conclusions

Since the establishment of LADM as an International ISO many country profiles have been implemented. Some of them have minor differences with the proposed classes of the ISO, whereas some others introduce new classes according to the particularities of its country. Apart from the three LADM country profiles mentioned in this chapter much more have been investigated. From those it is concluded that in most of the cases the countries have minor adjustments on the administrative (legal) part of the classes of ISO 1952, whereas at the spatial part they introduce new classes or extra attributes on the existing classes.

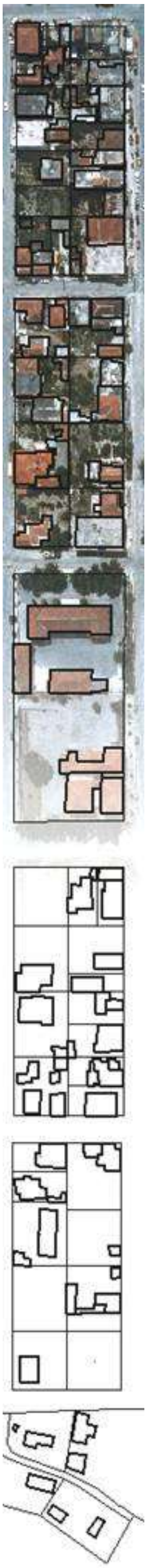
The code lists of each county are adjusted to each legislation system and the external classes enable the linking between the legal aspect of the registrations with the physical aspect which can be imported from another database, outside of the LADM country profile.

The three profiles that are presented in this chapter have been recently created and also focus on the spatial part of the model. In particular, the Malaysian profile differentiates a lot at the spatial part form the ISO 19152 classes by using the level concept and create sub-classes from each one of the different kind of spatial units in Malaysia.

Additionally, all of them show the flexibility of the LADM and the opportunity to use it as a reference model and based on that derive a technical model. In the three cases a prototype is developed starting from the use of LADM as basis for the conceptual model, continuing with the creation of a technical model based on the conceptual, then sample real data are implemented into the database and at the end the result is visualized in an (interactive) interface where 2D/3D queries can be executed.

Part II

Hellenic Cadastre



5. The Hellenic Cadastre

The Hellenic Cadastre (HC) is a unified and constantly updated system of information that records the legal, technical and other additional details about real estate properties and the rights on them.

The Hellenic Cadastre is an ongoing project expected to be completed due to 2020. This chapter presents the plan and the progress of the Hellenic Cadastre since its birth. The Greek government and in particular, the National Cadastre and Mapping Agency S.A. is the responsible organization and has the mission to study, develop and operate the Hellenic Cadastre. Its goal and scope is analyzed here together with the Infrastructure Programs that have been created in order to support the project of the HC.

5.1. The two systems of Land Record Management in Greece

Greece is in a transition period the last years moving from the "*Mortgage Office*" system to a fully digital Cadastral System. The development of the Hellenic Cadastre aims at the creation of a modern, fully automated real estate property record, whose details are of an evidentiary nature, ensuring the best publicity and security of transactions.

5.1.1. Registration and Mortgages System

For the majority of areas throughout Greece the System of Registrations and Mortgages is still the method for the registration of legal titles regarding the transfer of a property. This system is based on the person or entity that owns the land at any given time. Under this system a copy of each deed of transfer of property rights is deposited in the deed registry in a chronological order.

It is not possible to locate a property in the Mortgage Office archives based on its address or location. The registry is supplemented by a land charge register, which provides information about charges, mortgages, real servitudes and property claims. In addition, an index of names of vendors, of purchasers and of claimants is provided, related to the Volume and folio in which the deed is registered. You must know the name of the last person who legally owned the property. The property will be listed under their name. So if you are researching at the Mortgage Office to determine the status of a title, and there is no deed on file, you will be unable to locate the property.

The registration of parcels is usually coupled with an extensive verbal description of boundaries or/and a graphical plan, attached to every transaction, obligatory since 1977 and deposited to the Notary Public [Zentelis and Dimopoulou, 2001]. In regions where the cadastral survey remains in progress, Land Registry Offices are still valid, operating alongside with the corresponding Cadastral Offices. Besides, the legal definition of real property provided by the old system does not always reflect the actual condition on the terrain and this situation creates further confusion in the manipulation and management of land issues within the Greek territory and best evidence cannot easily be proved.

In particular [Tsiliakou and Dimopoulou, 2011] mention that deeds do not contain 3D information related to the heights applying on real estate, but relevant descriptive information. The only exception is when the legal description in deeds is accompanied by topographical plan including coordinates and/ or heights. Additionally, Land Registry Offices retained legal information related to land parcels and this information was (and still is) updated by new deeds describing recent transactions on real property. Similar problems apply for the HC project, since only the legal information is updated, while there is no capability for local offices so far, to maintain and update spatial data.

5.1.2. System of Operative Cadastre

Upon completion of the cadastral survey of a region, the system of "*Registrations and Mortgages*" is replaced by the system of "*Operative Cadastre*". Under this Land Registry system, all properties are catalogued by both their street address and the name of whoever proves ownership (the legal owner, a trespasser). In case that no one appears to claim ownership, the property is characterized as "of *unknown owner*": which if no one with a rightful claim comes forward, will eventually end up being claimed by the Greek state.

The New Land Registry System will allow for both the location of the property to be tracked as well as the name of the current owner of the property. So feasibly, in the near future, if you wish to research the legal status of a property, you will not need the name of the current owner, you will just need the address.

The system was designed as a parcel-based land information system, serving as a legally recognized record of land ownership. The aim of the project is to establish a complete, uniform, systematic and always up-to-date registration of land parcels in Greece and guarantee titles to those parcels brought on to the register by the adjudication process, issued according to relative legislation [Law 2308/1995 & 2664/1998]. These registrations consist of the geometric description of the parcels and the ownership situation on them. The procedure of collecting and maintaining the data is overseen and guaranteed by the Hellenic State. The project also, aims to include additional valuable information, which is necessary to support developing activities of the country.

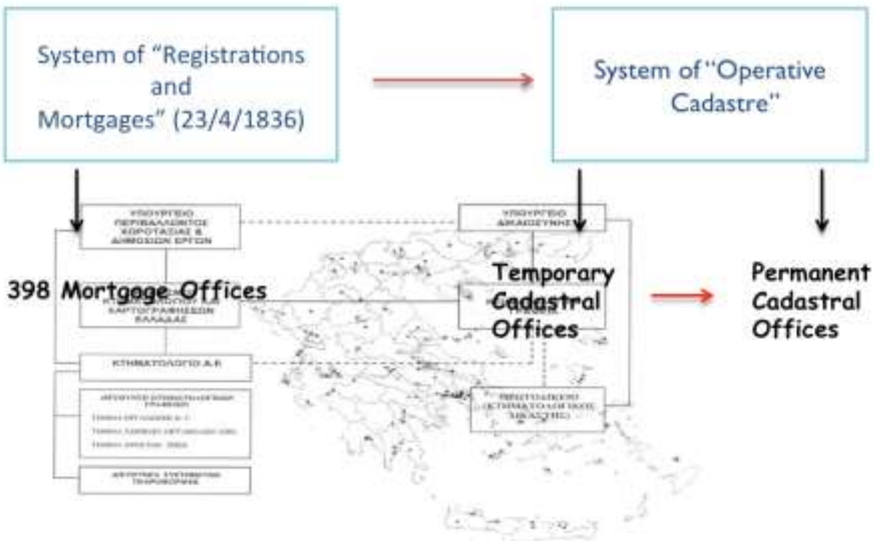


Diagram 5.1: The transition from one system to the other [Kalogianni et al, 2014].

In a nutshell, the Hellenic Cadastre is an integrated system, admittedly more effective than the old system of registrations and mortgages supported by the Land Registry Offices. By registering their properties in the Cadastre, owners achieve the full registration of information relating to each and every property individually, combining both spatial and legal details.

5.2. The HC Project

The HC project started in 1994, based on an initiative of the Ministry of Environment, Physical Planning and Public Works [now is renamed as Ministry of Environment, Energy and Climate Change], the financial support of the EU [2 Community Support Frameworks] and the Hellenic State. Ktimatologio S.A. [now renamed to NCMA S.A.] established by a joint decision of the Ministries of National Economy and Environment, Physical Planning and Public Works [M.D. 81706/6085/6-10-1995 MDGG872B/19-10-1995] executed this project in co-operation with a private consortium, the Hellenic Cadastre Consult [HCC] for the promotion of the project.

The purpose of the project is the systematic collection, registration, organization and multipurpose management of the spatial information in relation with its legal/ownership status all over the jurisdiction.

Some of its main features are:

- Guarantee the land tenure and improve the land market,
- Safety of publicly owned land,
- Elimination costly and time-consuming paper-work and bureaucratic procedures,
- Assistance of the management of land and monitoring of land use and
- Facilitation of the sustainable development and environmental protection.

Responsible for preparing strategies and providing the necessary infrastructure data (topographic data and aerial photography) is the Hellenic Mapping and Cadastral Organization (HEMCO) [Law 1647/ 1986], a governmental organization under the Ministry of Environment, Physical Planning and Public Works. The development of the Hellenic Cadastre relies greatly on the collaboration between public sector and private surveying engineering companies, who have the means to complete the tasks contracted to them by Ktimatologio / HEMCO.

The project comprises so far two pilot programs and the 1st main program. It is expected that the ongoing cadastral works within this framework will cover 16% of urban areas, 10% of agriculture land and 7% of forestland areas, in 447 municipalities. In its operational phase the cadastral activity will be undertaken by regional and local cadastral offices, responsible for maintaining and updating cadastral maps and registers. The setting up of these offices will at first correspond to the existing mortgage bureaus, in order to ensure that legal support will be provided for the first registrations. Further on the system will be developed towards the establishment of an information system that will upgrade all cadastral activities, and provide the end users of the system (landowners, associated organizations, etc.) with the necessary certificates containing all information concerning property rights, transfers of rights etc. This will greatly facilitate all legal transactions [Zentelis, 2001].

The Hellenic Cadastre introduces innovations that constitute it a truly fundamental project for Greece, resulting in significant benefits for the citizens, Hellenic economy and the protection of environment.

The Hellenic Cadastre:

- Proceeds to the definite, without contestations, registration and consolidation of the citizens' real property.

- o Limits bureaucracy and real estate property transfer procedures become simpler and faster.
- o Reinforces transparency and security in property transfers.
- o Upgrades the real estate property market and raises the property value so that significant investments are attracted.
- o Demarcates irrevocably and ensures State and municipal property.
- o Protects the environment more effectively. The irrevocable demarcation of forests and coastal zones will constitute a most serious impediment against encroachment and arbitrariness.
- o Constitutes a pivotal tool for the sensible organization and development of the country.

5.3. Legal Framework

Registration of all the rights exercised by the owners to their properties, all over the Greek territory. The problem is that the public property is not yet recorded in its whole in a national scale. This means that there is no knowledge for its extent, leading to infringement from individuals.

This is due to the fact that Public State was not obliged to register its properties since July 2013 according to the existing legislation. However, according to the Law 4164/2013 the Greek State is obliged to register all its properties.

Cadastral legislation dates back 1n 1995, when the HC projects started and since today multiple laws have been formed changing the legal framework. The most important are: L. 2308/1995, L. 1664/1998, L. 3127/2003, L.3208/2003, L. 3481/2006 and L. 4164/2013. Additionally, the Civil Code of 1964, the cadastral law of the Dodecanese islands and the concept of Byzan-Roman law "*superficies solo cedit*" [what lies above or below the surface belongs to the owner of the corresponding land-parcel] are dominant frameworks for the operation of the HC.

For the horizontal ownership Law 3741/1929 about "*ownership per floor*" or "*ownership of mines*" together with the current Civil Code about "*horizontal co-ownership*" are the most important frameworks. Therefore, the Civil Code ["*legal implantation right on foreign land*", "*surface or separate ownership legal right on plantation, trees or constructions on foreign land*"] and the customary laws of Cyclades islands ["*possessor of the ground-floor is the sole owner of the land-parcel and the subsoil*"] are the framework for the complex properties [Papaefthymiou et al, 2004]. Additionally, the customary law, which applies to several Aegean islands, controls legal relations on ownership rights, such as joint properties, constructions on foreign parcels, etc. is milestone for the HC as it concerns unique cases. SRPO apply in this case as well.

After a comparative review of all countries' questionnaires concerning 3D Cadastre, Tsiliakou and Dimopoulou [2011] mentioned the main deficiencies of the Greek legislative framework regarding the registration of 3D objects:

- o There is no generic or specific legislation stipulating the three-dimensional description of objects, even in a 2D way.
- o There is no specific legislation describing the specifications for surveying plans in 3D, even in 2D. Note that the Dodecanese's Cadastre is separated and provides floor plans per floor of property additionally to the cadastral plans of land parcels. Consequently, a clear view of the allocation of rights in the vertical component is provided.

At this sub-chapter two of the most important laws for the HC project will be briefly introduced: Law 3481/2006 and Law 4164/2013. Apart form them, different kind of rights will be further analyzed.

5.3.1. Law 3481/2006

Law 3481/2006 set the Hellenic Cadastre on new foundations with regard both to the cadastral survey, since the law simplifies and speeds up the survey's completion and ensures at the same time the project's financing, and to the implementation of the Cadastre's institution.

More analytically, the most important changes that this legislative amendment brought about are the following [http://www.ktimatologio.gr]:

1. The time and cost of the cadastral survey procedure are reduced. The second public presentation (suspension of data) is abolished and the relevant processes are merged in the context of a single public presentation (suspension). The collected data will be crosschecked and verified. Following that, they will be publicly presented only once, so that the interested parties can submit either correction applications for simple (obvious) mistakes, or objections to be judged by a committee, in which a judicial officer will be presiding.
2. The correction procedure for the so-called "obvious mistakes" of the initials registrations is simplified. Following a simple application filed by the interested party to the Head of the competent Cadastral Office, the latter can correct the so-called obvious mistakes, which refer to any detail of the registration and mainly to the beneficiary, the right, the ownership title and the real property, observing certain conditions which guarantee that the correction does not involve any arbitrary modifications.
3. The procedure of judicial correction of the registrations referring to an "unknown owner" is accelerated and simplified. In case a citizen does not submit an ownership declaration during the cadastral survey procedure, their property is registered in the Hellenic Cadastre flagged to belong to an "UNKNOWN OWNER". Provided the beneficiary holds official legal deeds, he/she can request the correction of the relevant registration even after the completion of the cadastral survey. Up to now, the correction was possible only through a strict, expensive and time-consuming judicial procedure. Corrections of this type will be now performed through a simple and timesaving procedure of "voluntary jurisdiction", in which the court decides upon the correction request without any litigation and the procedure is completed in a very short period of time. This way, the guarantee of judicial control is maintained and transactions are facilitated.
4. The project's financing is assured. The cost of the Cadastre is estimated at about 1.5 billion Euros. Since it is no longer financed by the European Union, we proceeded with the self-financing of the project with a realistic and just "cadastral fee". Furthermore, the State will contribute to the project an amount of about 260 million Euros.

5.3.2. Law 4164/2013

At a time when the reorganization of the public sector of our country and the improvement of its competitive position in the international environment constitute a primary -national- objective, the National Cadastre, as a key development tool, enters into a new phase, further improving the conditions of operation and application of the institution with the passing of Law 4164/2013 about "Supplementation of the provisions governing the National Cadastre and other regulations" [Gov. Gazette 156/A΄/09.07.2013].

The new Law on the National Cadastre contains important regulations that safeguard the public property and facilitate the transactions of citizens in the context of both the cadastral survey procedure and the operation of the Cadastre.

The law's main objectives are, among other things, the acceleration of the cadastral survey, the simplification of the procedure for correcting initial registrations, the cutting of red tape, the introduction of a system for online remote service. In this way, a significant saving of resources is achieved, and the Cadastre is rendered more functional and more citizen-friendly. An important development is also the establishment of the State's obligation to submit declarations, which will lead to the complete recording of public property, with a view to protecting and exploiting it.

In this context, the new law contains regulations for the quick and unhindered progress of the necessary calls for tenders, by shortening the tendering procedure for the awarding of studies by one stage. This regulation boosts to the maximum extent the acceleration of the awarding and completion of cadastral survey studies until 2020, but also of other contracts for the development of studies or the provision of services that are directly related to the National Cadastre, such as the formation of forest maps.

The legislative regulations regarding the operation of the Cadastre include the digitization of the transactions with the Cadastral Offices, such as the online submission of petitions for the entry of registrable deeds, the issue of certificates and the long-distance search in the cadastral records. The company "NATIONAL CADASTRE AND MAPPING AGENCY S.A " (EKXA S.A.) undertakes the organization, structure and logistical support of the operation of Cadastral Offices, while at the same time provision is made for the possibility of providing central support to the Cadastral Offices and the making available to them of specialized personnel to assist their work and, in general, to meet their operational needs.

5.3.3. Rights in Real Property

In Greece, the Property law, as part of the Greek Civil Code, regulates the main issues related to ownership. Apart from the Civil Code, other Greek Codes (e.g., Code of Civil Procedure, Commercial Law, etc.) and various special laws (such as "*on ownership per floors*", "*on compulsory expropriations*", or "*on the provision of mines, caves and archaeological sites*") contain rules regarding property rights.

Some recent reforms affecting real estate property in Greece are more associated with environmental issues, residential needs and better land organization, within the framework of information society, and of course the ongoing project of the Hellenic Cadastre, which will undertake the registration of all real property in Greece according to Laws 2308/1995, 2508/1997, 2664/1998 and 3127/2003.

Under the Greek legislation, whatever lies above or beneath the surface of the earth belongs to the owner of the corresponding land-parcel (with the exception of some mines). Therefore, the ownership of a part of land generally includes all the buildings that have been constructed on it (article 954 C.C.). An exception to this principle is the establishment of horizontal and vertical property according to article 1002 C.C. in combination to Law 3741/29 "buildings that are built on a uniform plot" correspondingly.

After the introduction of the Greek Civil Code the articles 1002 and 1117 have set the basic principles of the "*horizontal ownership*". As a result, exists the individual ownership of the apartment combined with the joint ownership of the land. The owners of the land where the block of flats is built or shall be built can set up this separate ownership only with a notarial act, which must be registered, or with a will in an existing apartment or in a future one (Mattheou, 2004).

Another exception to the principle that "*the objects lying above belong to the objects lying underneath*" is established by the article 1010 C.C.: building party on an outland real estate. Apart from this stipulation, other interests in land, such as different servitudes, give the benefit of the owner or possessor of other land; such as easement of passing through. They are distinguished in negative and positive ones and are regulated by the articles 1118-1141 of the C.C [Dimopoulou et al., 2006].

5.3.4. Customary property rights

Customary rights still remain in some parts of the world regulating the creation, possession, use and transfer of RRRs. Customary law, controls legal relations on ownership rights such as joint properties, implantation privileges, constructions on foreign parcels, etc.

Mostly in the Aegean islands, the customary law regulates most legal relations on property rights. Particularly in the Cyclades, due to the lack of space, the ground's intense relief and the socioeconomic conditions that prevailed, laws arranging the partition of land and buildings and establishing the succession to land property have been utilized. Customary law was the regulator of the transmission of property from one generation to the next, resulting in the structure of the type of property devolved [Dimopoulou et al., 2006].. In order to give dowry and secure the best possible their children, parents adopted various customary strategies, concerning their family property [Kasdagli, 2004].

Property rights are based on multiple legal frameworks (such as statutory, customary, case and local laws), which co-exist, influencing each other in the course of time. This multiplicity and interaction between legal orders eventually result in significant property law modifications, which in turn contribute to increase tenure confusion and uncertainty, especially for less favored groups. In other words, property rights should be legally "well- defined", in order to provide tenure security and efficiency in use [Meizen-Dick&Pradhan, 2002].

Greek legislation contains contradictory laws regarding the definition and management of property rights, which is rather confusing. It is evident that there is a need to perform relevant reforms in order to overcome this situation. According to (Tsiliakou and Dimopoulou, 2011), an arrangement would be to reform old laws such as (superficies solo credit) Article 954 of the Civil Code, while reviewing and redefine those applied to comprise the description of three-dimensional objects.

Joint ownerships, implantation rights or constructions on foreign land and ownership on a specific part of property, are some of the custom derived cases. In some of them, the owner of the legal right might have no percentage on the ownership of the land-parcel, while the owner of the ground floor is the 100% sole owner of the land parcel and its subsoil, and the owner of the upper floor is the sole owner of the air, unless it has already been transferred to another person [Papaefthymiou, et al., 2004].

5.3.5. Special Real Property Objects [SRPO]

The concept of "Special Real Property Objects" has been introduced in accordance to the Statement of FIG for Cadastre 2014 [Kaufmann, 1999 and Rokos, 2001]. The SRPO include [Tsiliakou and Dimopoulou, 2011; Papaefthimiou, 2001], see Figure 5.1:

- **Anogia**: high-level constructions built, some bridging roads or paths, very common on Greek islands and traditional villages.
- **Katogia**: constructions built below ground level.
- **Yposkafa**: dug-in houses, very common in many Greek islands.

- **Syrmata**: typical seaside spaces common on islands of Cyclades, which have a special mechanism to draw the boats inside during the winter.
- Arcades
- Tanks
- Wells
- **Arches:** structure spanning a space while supporting weight.
- Windmills
- **Domes:** byzantine constructions functioning as large warehouses.
- Mines.

Figure 5.1: a-Anogeio, b-Yposkafa, c-Syrmata, d-Arch, e-Windmill, f-Domes [Tsiliakou&Dimopoulou, 2011].

5.4. Organizational Framework

Complex organizational framework concerning the Hellenic Cadastre, as there are many stakeholders, such as Ministries, institutes and regional authorities involved in the process and also there is a significant number of laws dating from 1995 to 2013. Table 5.1 depicts the databases and registries maintaining real property data in Greece today [Kalogianni et al. 2014].

Geographical data are at disposal of the Hellenic Military Geographical Service [IMGS]. Until 2013, there was no centralized coordination of relative institutions or agencies that maintain the main registries. Therefore overlapping data produced by various authorities is common as data is not systematically organized and may also exist in different reference systems. Since 2013, an electronic document submission from the owner to municipal Urban Planning Offices for issuing of building permits is required. Unfortunately, until then, in many registries the data is in analog format.

Registries, Databases, Maps	Data
Hellenic Cadastre/ *Mortgage Register Offices*	- Real property boundaries and RRRs - National datum coordinates - Building footprints - Real property owned by the State - Sea-shore and forest land (ongoing) - Areas to be expropriated for public constructions (not yet recorded) - DTM/ DSM/LSO/VLSO - *Deeds(that may include survey drawings or sketches)*
Municipal/ Regional Urban Planning Offices	- Documentation required for issuing building permits (construction drawings, plans of survey, cadastral sheet) - Municipal street level
Utility operators	- Maps of individual utility networks
Thematic Cadastres (mainly maintained by separate ministries such as Ministry of Rural Development and Food, Ministry of Environment, Energy and Climate Change and Ministry of Culture and Sports)	- L.P.I.S - Mineral activities (to be incorporated to the HC) - archaeological sites, historic places, protected locations of the cultural environment and monuments (Archaeological Cadastre) - Forest maps (not completed-to be incorporated to HC) - Municipal real estate property and constructions under municipal authority (Municipal cadastral offices) - Drawings and data of informal buildings or informal building parts
- Taxation databases - Municipal Registers (municipal tax) - Registry of Public Power Corporation	- Use of real estate parcel/building - Location (defined by address) - Area - Ownership type
HMGS	- Aerial photography - Analogue maps and digital data - Topographic products
Hellenic Statistical Authority	- Digital cartographical data (based on HMGS maps including the axis' of the streets and their names (when possible), the outlines of the blocks and their numbering, the outlines of the buildings and their numbering within the blocks) - Data related with building and construction activities

Table 5.1: Authorities responsible for registries and databases in Greece.

5.4.1. National Cadastre and Mapping Agency S.A.

The company was founded with a joint decision of the Minister of Economy and Finance and the Minister of Environment, Physical Planning and Public Works [Decision 81706/6085/6-10-1995/Government Gazette 872B/19-10-1995]. NCMA S.A. operates according to the rules of private finance and the provisions of article 5 of Law 2229/1994, of the coded Law 2190/1920, of Law 2308/1995 and Law N.2664/1998, as these stand today.
[http://www.ktimatologio.gr/sites/en/aboutus/Pages/qoQhyNCvtozm6ajS_EN.aspx].
Furthermore, the company does not fall under the class of organizations and businesses of the broader state sector; regulations that concern companies directly or indirectly owned by the State do not apply to NCMA S.A.. The sole shareholder of the company is the Ministry of Environment, Energy and Climate Change [http://inspire.ec.europa.eu/index.cfm/pageid/42/list/6/id/16506].

The development of the Hellenic Cadastre aims at the creation of a modern, fully automated real estate property record, whose details are of an evidentiary nature, ensuring the best publicity and security of transactions. Specifically, the main activities of the NCMA S.A. are:

- To establish the HC in the country. This is accomplished through a staged approach that involves designing, planning, and carrying-out the cadastral surveys in areas to be incorporated into the Hellenic Cadastral System.
- Records all deeds that establish, transfer, change or abolish rights on properties on a real property-centered basis. Thus, everything becomes simpler and more definite.
- Guarantees all legal details it records, since every deed is registered only after its lawfulness has been checked, meaning that no deed is registered if the transferor is not the person that the cadastre shows to be the beneficiary.
- Records the geographical description [shape, location and size] of the property too.
- Unveils and systematically records the State real property for the first time in contemporary Greece.
- Records the rights evoking from usucaption, which, especially in the province, may constitute the most usual way of ownership acquisition due to the informal nature of transactions.
- To support [technically, legally] the operation of the cadastre in areas in which the system has been established.
- To operate the Hellenic Positioning Service [HEPOS], which provides, through a network of approximately 100 permanent GPS stations, centimeter-level accuracy measurements to users throughout Greece.
- To compile large scale color orthophotomaps (~1:5.000) for the entire country and very large scale (~1:1.000) color orthophotomaps for the urban areas of the country.
- To compile specific purpose base maps (about forests and the shore) that are necessary for establishing the cadastre in an area.
- To operate the IT System of the Hellenic National Cadastre.
- To support legally and technically the operation of the cadastre.

Ktimatologio S.A. has followed closely the developments about the INSPIRE Directive since the initial steps of the initiative. Most of its input, however, has been made through the Hellenic Mapping and Cadastral Organization (HEMCO), which is the coordinating agency in Greece on issues about the INSPIRE. It must be noted that both agencies, HEMCO and Ktimatologio S.A., belong to the Ministry of Environment, Physical Planning and Public Works and now they are merged in one organization called NCMA S.A.

I. Cadastral Survey

The implementation of the Hellenic National Cadastre covers 340 areas of the country, where smaller cities and villages are included. The development of Cadastre, "cadastral survey", at a region is defined as the procedure of recording the real property or other registrable rights [e.g. full or limited ownership, usufruct, prenotification or other real property encumbrance, etc.], which a person or a legal entity has on real properties of a specific region of the country and the connection of these rights to a specific property or properties, as the latter are defined and depicted, after being checked and technically processed, on cadastral diagrams.

On recording a real property right, a series of legal details (register and ID details of the beneficiary, way of acquisition of the right, details of the deed with which the right was acquired, etc.) are also recorded. Furthermore, land parcels are depicted on cadastral diagrams in absolute accuracy with specific node coordinates that refer to the Hellenic Geodetic Reference System [EGSA '87], specific boundaries and property areas.

Consequently, the cadastral survey procedure aims at collecting, processing and recording property and other registrable rights per property, but also at collecting and processing details that allow the most accurate possible depiction of land parcels on cadastral diagrams.

The cadastral survey as it is organized today has a specific time schedule. It begins with the declaration that a region is under cadastral survey and it is completed with the commencement of the Cadastral Office's operation in this region.

Briefly, the cadastral survey procedure includes the following stages:

- **Submission of property declarations** to the Cadastral Survey Offices by the beneficiaries and registration of the declaration in a digital database. The beneficiary can go by himself/herself or send a third party to the competent Cadastral Survey Office, or submitted it on-line in the appropriate form. In case that a beneficiary did not submit an ownership declaration in due time, he/she can submit an overdue declaration during the cadastral survey; however a fine is prescribed in this case.
- **Formation of interim cadastral tables and diagrams** based on the data that has been collected from the submitted declarations and has been processed by lawyers and surveyors. The tables will be suspended at the Cadastral Offices and the Municipalities. The Suspension procedure will allow citizens to check the content of the registrations and to submit objections to any errors or oversights.
- **Suspension of the interim cadastral data** [tables and diagrams] at the Cadastral Survey Offices for a two-month period and dispatch of extracts to the beneficiaries for their information. The suspension of cadastral data is a particularly important point in the process of drafting the National Land Registry. In this way, everyone is given the opportunity to verify, confirm or even correct possible errors.

The Suspension consists of:

a. The **Cadastral Table**, which includes all property rights for a region, as substantiated by deeds and other data collected during the survey process. The table is organized according to "KAEK" (National Cadastre Code Number), which is a number unique to each property.
b. The **Cadastral Chart**, where the geometrical data of properties is shown (position, limits).

- **Submission of objections** to independent administrative committees or **applications for the correction of a cadastral registration**, depending on the case, by whomever has a legal right, for a time period of two months for residents of Greece and a time period of four months for people residing abroad.
- **Reformation of cadastral data** after the examination of the objections and the correction claims and **formation of the final cadastral tables and diagrams**. The registrations that appear on the final cadastral tables are called Initial Registrations since they constitute the first (initial) registration in the cadastre.
- Commencement of the Cadastral Office's operation in the particular area in place of the old Land Registry Office.

Initial registrations in the HC project are the ones that appear in the cadastral book of a region, as transferred from the cadastral tables, after the completion of the cadastral survey and before the commencement of the HC operation in that specific region. Every posterior registration of a right is based on the initial registrations.

Properties (or rights on properties), which for any reason were not declared during the cadastral survey, are recorded in the cadastral database as belonging to an "Unknown Owner". For the correction of the initial registrations of "Unknown Owner" into a known owner, the same procedures –judicial or administrative correspondingly depend on the case- with the ones for the erroneous registrations stand. Specifically, the interested party should comply with the correction procedures that are laid down, after he/she has already located their property.

Each registered property, building, etc., gets a code number of National Cadastre [KAEK], a 12 or 16 digit unique number.

From these digits:

- The first two digits correspond to the Prefecture of the country,
- The next two digits to the sector of each Municipality or Community,
- The next two to the sector of each municipality
- The next two to the building square and,
- The three next to the number of the building plot.

If it is a horizontal property [apartment, office or shop] four extra digits are added:

- The next two correspond to the serial number of the building block of flats].
- The last two digits to the floor and the place of the particular horizontal property.

All the data of the National Cadastre will be registered in computer files. The research of recovery of the householder of each piece of property may be organized by:

- The address of each property, or
- The code number of each property.

When the HC will be completed it will be also possible to search by the name of the property owners in the entire country.

5.4.2. Archeological Cadastre

The Hellenic Archaeological Cadastre is the first organized, on-going and systematic digital registry for:

- The Public Assets (Real Estate) managed by the Hellenic Ministry of Culture and Tourism,

- o The Protection Areas of Cultural Environment including Archaeological Sites, Historical Places, Protection Zones, Peripheral Protection Zones [buffer zones], etc.,
- o The Ancient and Modern Immovable Monuments.

It is anticipated to become a valuable source of reliable information regarding the rich Cultural Heritage of Greece, as it will include detailed data on ownership and acquisition status, the historical identity of each Site and Monument, precise geospatial data, and more. All information managed by the Archaeological Cadastre will be provided under the responsibility and the warranty of the Hellenic Ministry of Culture and Tourism through publicly available Electronic Services.

At the moment, the project is at the implementation stage. One of the main goals is the development of an Integrated Information System that will be populated with: nearly 6.000 entries relating to Public Assets (real estate) i.e. urban and suburban land plots, agricultural parcels, buildings and other artifacts, that have been acquired by the Ministry of Culture and Tourism. Nearly 18.000 entries relating to Protection Areas of Cultural Environment and Monuments.

At the following figures an example depicts the information registered in the Archeological Cadastre today.

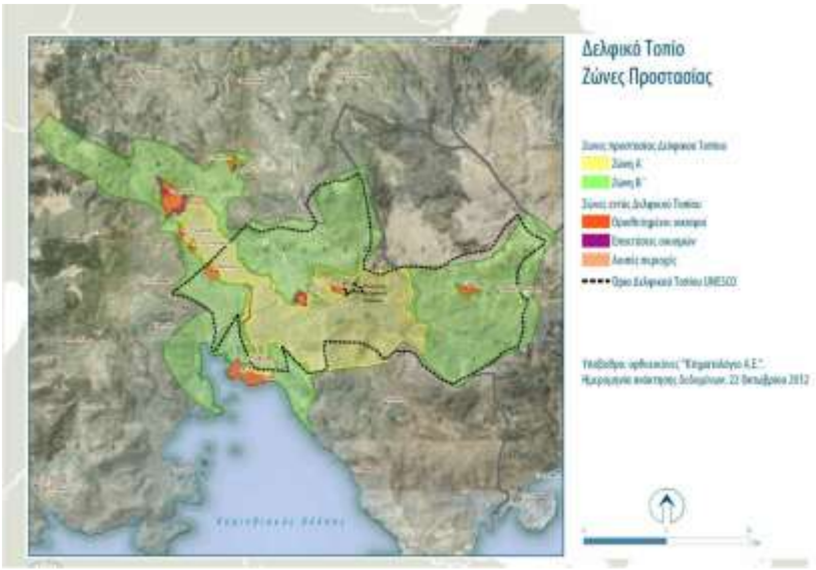


Figure 5.2: Protection areas in archeological site represented as polygons [http://archaeocadastre.culture.gr]

Figure 5.2 represents the protection areas in an archeological site at the historical area of Delphi, which behave as restriction zones. With yellow color 'Zone A' is represented where no building activity is permitted at all; and with green color 'Zone B' where limited activities are permitted.

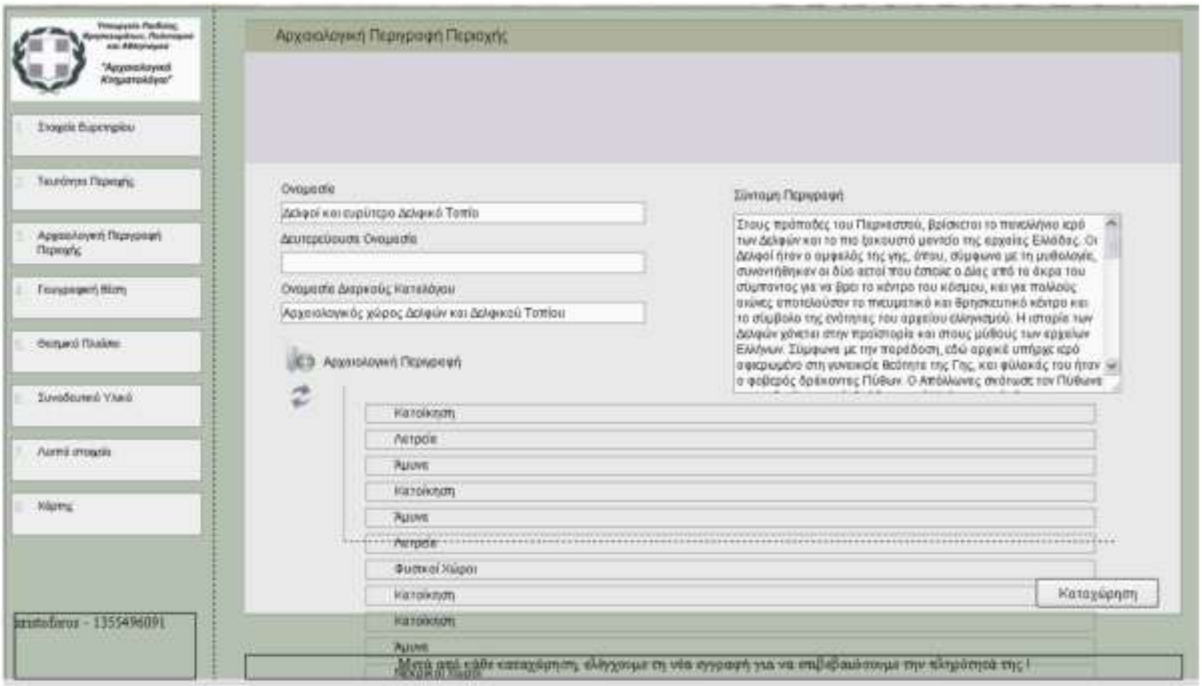


Figure 5.3: Attributes related to the area presented in Figure 5.2. [http://archaeocadastre.culture.gr].

Figure 5.3 shows the form where the attributes of the spatial data are stored. In this example, the attributes corresponding to the area shown in Figure 5.2are represented. It includes the following information:

- • the name of the archeological site,
- • the official name of the site stored in the archeological catalogs,
- • a short description,
- • an archeological description,
- • the location of the site,
- • the legislation framework,
- • important links or information form external sources and
- • a map

The strategies adopted by the Archaeological Cadastre will be coordinated with the Hellenic National Cadastre. Moreover, the computing infrastructure will serve as a central platform, available to the entire Ministry, easily expandable to incorporate and connect to future information systems and data sources. Such systems may be the Cultural Atlases, the Information System of the National Archive of Monuments, various outcomes from topographic surveys, data from archaeological findings and excavations and so on.

The project is currently being developed and managed by the Department of Expropriations and Real Property [http://archeocadastre.culture.gr].

5.5. Infrastructure Projects

NCMA S.A. has implemented a series of supporting actions under the title "Data and I.T. Infrastructure for a modern Cadastre" along the lines of the "Information Society" Operational Plan, part of the 3rd Community Support Framework [CSF]. The supporting programs were co-financed by the EU and y the Greek State.

The goal of the co-financed projects of the 3rd CSF, which introduced a new managerial approach and utilized the latest technological developments, is to organize and prepare the continuance and completion of the Hellenic Cadastre in a more effective and inexpensive way.

The 3rd CSF projects comprise the following supporting actions:

<u>Development of a Digital Database of the "active" titles coming from the Land Registry Offices in urban centers.</u>

The action involved the development and maintenance of a digital database that contained all data included in the ownership declarations submitted in 107 regions of the State. This database is called "active titles database" because it recorded all valid rights on real estate properties standing today in these regions.

The ratification of the collected rights will be performed with cadastral survey projects that will not be financed by the 3rd CSF.

<u>Digitization and conversion of existing maps / registers</u>

Digitization of data from land consolidations and re-distributions for the entire State: This action aims at the development of a digital database that will contain all cadastral data included in the land consolidations and re-distributions of the Ministry of Rural Development and Food.

<u>Hellenic Positioning System - HEPOS</u>

This system makes use of GPS technologies so that for every measurement performed using this system the co-ordinates of a point within Greece are determined in minimal time, at a low cost and with high accuracy [2-4 cm in real time]. The HEPOS system is being used as the base for the cadastral survey already in progress in 107 regions of the country [Figure 5.4]. At the same time, it will also serve the needs for the development of the Hellenic Cadastre in the future years.

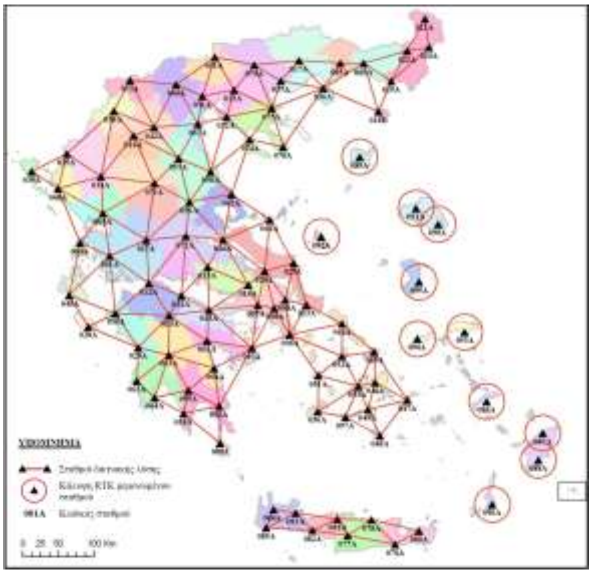


Figure 5.4: The 98 HEPOS bases [http://www.hepos.gr].

<u>Digitization of the Dodecanese Cadastre</u>

The cadastral survey data of the Dodecanese Cadastre (Rhodes, Kos and part of the Leros Islands) are digitized and automated in such a way so that it is compatible with the Hellenic Cadastre database. At the same time, the content of the developed database will faithfully represent the respective analog information of the Special Dodecanese Cadastre, without correcting spatially or improving the content of its data at any phase.

Development of Unified National Basemaps

The basemaps required for the new cadastral surveys are developed using geometrically ortho-rectified images with high spatial analysis and accuracy. Color digital orthophotomaps with a pixel size of a 20cm rate [Figure 5.5] are produced for the major urban areas of every prefecture. In addition, digital orthophotomaps with a pixel size of approximately 50 cm are produced for the entire State.

Figure 5.5: Screenshot of a digital orthophotomap [www.ktimatologio.gr]

Collection of suggestive / indicative data for the facilitation of the cadastral survey procedure

Delineation of forests and forest areas for the entire country

Forests and forests areas are delineated based on aerial photographs from 1945 / 1960, recent basemaps, recent satellite data and recent aerial photos. The estimated are covered by forests and forest areas in Greece is 95.3 stremmas. The outcome will be a preliminary product that will facilitate the development of forest maps. It is clear that without the boarders of the forests the operation of the HC project cannot be completed [Figure 5.6].

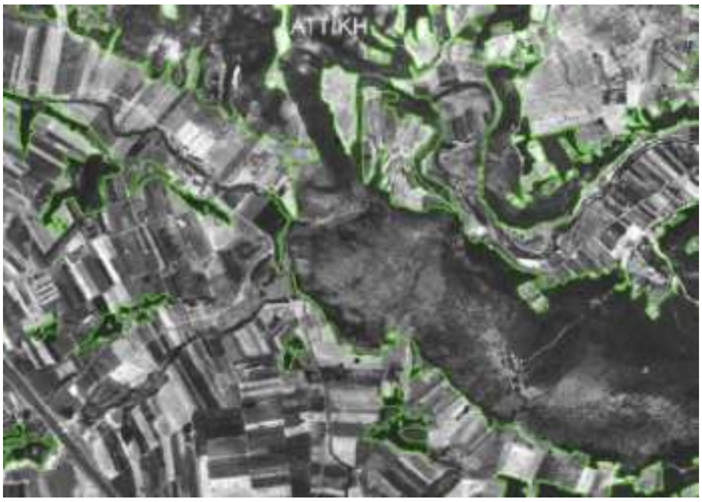


Figure 5.6: Delineation of forests and forest areas [www.ktimatologio.gr]

<u>Development of unified national basemaps appropriate for the delineation of coastal zones</u>

Development of digital orthophotomaps of high accuracy for the delineation of coastal zones. The project's objective was to develop color orthophotomaps of high resolution and accuracy [even objects of a 20cm size are represented] as well as a detailed digital elevation model of a certain zone along the coastlines, riverbanks and lakeshores nationwide.

The project aimed at developing the necessary basemaps and delineating the Preliminary Costal Zone for the largest part of the country with unified specifications and format. This data will be used, at a later stage, by the Services and Committees of the Ministry of Economy and Finance for speeding up the procedures in order to officially delineate coastal zones, older coastal zones, the seaside and riparian zones of lakes and rivers.

<u>Areas protected by NATURA 2000</u>

An important structural change, concerning protected areas, is brought about by the new law on the National Cadastre, 4164/2013. An authority is now designated to determine whether a real estate is found inside or outside a Natura area. In this way, different information from different agencies and sources is interlinked, and the location of each real estate inside or outside a Natura area is certified, giving a definite picture for each real estate in the country. So, EKXA S.A. undertakes to provide a new service at national level through the cadastral offices or the company: the provision of data and information about the limits of the Natura areas, certified as to their accuracy. The database will be updated as to the boundaries, based on the uniform basemaps that the institution possesses. In this way, comprehensive information will be provided on each real estate included in the system of the National Cadastre.

<u>Development of IT infrastructure</u>

The actions of this measure aim at improving and updating the IT infrastructure o NCMA S.A., so that it becomes the means for the management of the company's projects. The Web services that were developed so far are addressed to citizens [online submission of ownership declarations with the ability to identify the location of the property on a basemap], as well as to contractors of cadastral surveys [online application of registering and processing ownership declarations].

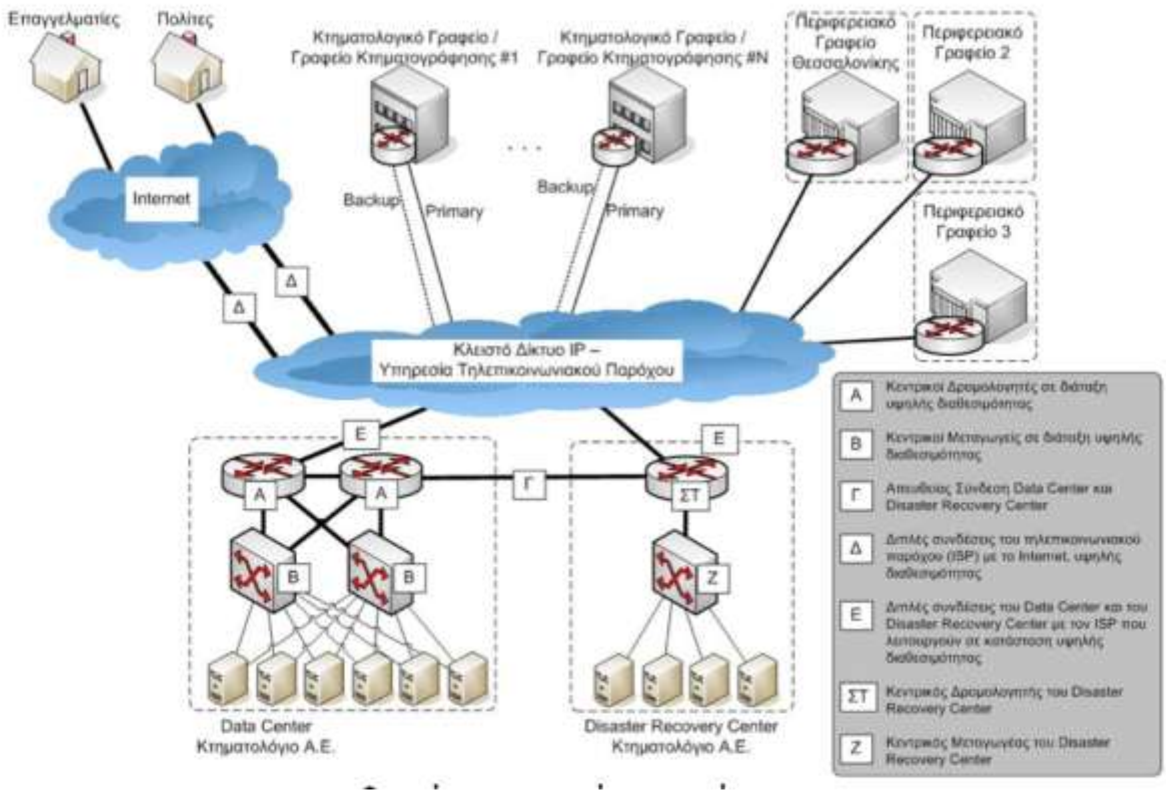


Figure 5.7: System Architecture

5.6. The Data Model of the HC

5.6.1. Cadastral model

The Greek Cadastral model has two phases of data modeling, the conceptual and logical design of the model.

I. <u>Conceptual model</u>

Error! Reference source not found.2 is the Entity – Relationship diagram of the entities used at the HC. It presents the general conceptual model that is currently being used by HEMCO SA today, as well as the topological relationships that exist among those entities (eg. For all cadastral data are not overlapping entities within the same layer). The model is parcel based and every part of land at the municipal level is a cadatrsl parcel (including roads, streams, special areas, etc.). Additionally, the spatial information is fully connected with legal and property information [Kavvadas I., 2012]. In order to check the quality of the cadastral parcels the Greek Quality Model for cadastral parcels has been introduced, which compiles with international standards (ISO 10005) and is mandatory to be implemented from HEMCO..

II. <u>Logical model</u>

After the creation of the conceptual model the next step involves its translation into the corresponding logical model and finally into the database. The transformation of the logical model into a physical database provides a better understanding at the conceptual level. The Hellenic Cadastre Data Model is translated from a Platform Independent model, as it was described using UML diagrams, to a Platform Specific Model, using an object-relational database model and in particular Oracle database,

5.6.2. Cadastral Database

The HC's descriptive and spatial information is organized in a property-centered base, thus search can be done either by the property's National Cadastre Code Number (KAEK) which is unique to each property, the address or the beneficiary name. The DBMS that is used from HC is Oracle

5.6.3. Digital descriptive database overview

The digital descriptive database includes the cadastral information that is collected and technically processed according to the specifications for the development of the HC.
The descriptive database of the HC describes the following:

- Properties,
- Beneficiaries or other parties that have any kind of right on a property,
- Rights and the corresponding documents,
- Information necessary for the cadastral survey,
- Multiple standard comments.

The following figure shows a screenshot of the table BEN and some of its relationships with other classes. The complete diagram of the descriptive database is presented in the Annex A.

The spatial data are stored in the database. For visualization purposes ArcGIS server of ESRI, Openlayers API or WMS [Web Map Service], as well as Javascript browsers are used. The descriptive information is maintained in the database Oracle 10g and is visualized with Microsoft.net [Tsiliakou and Dimopoulou, 2011].

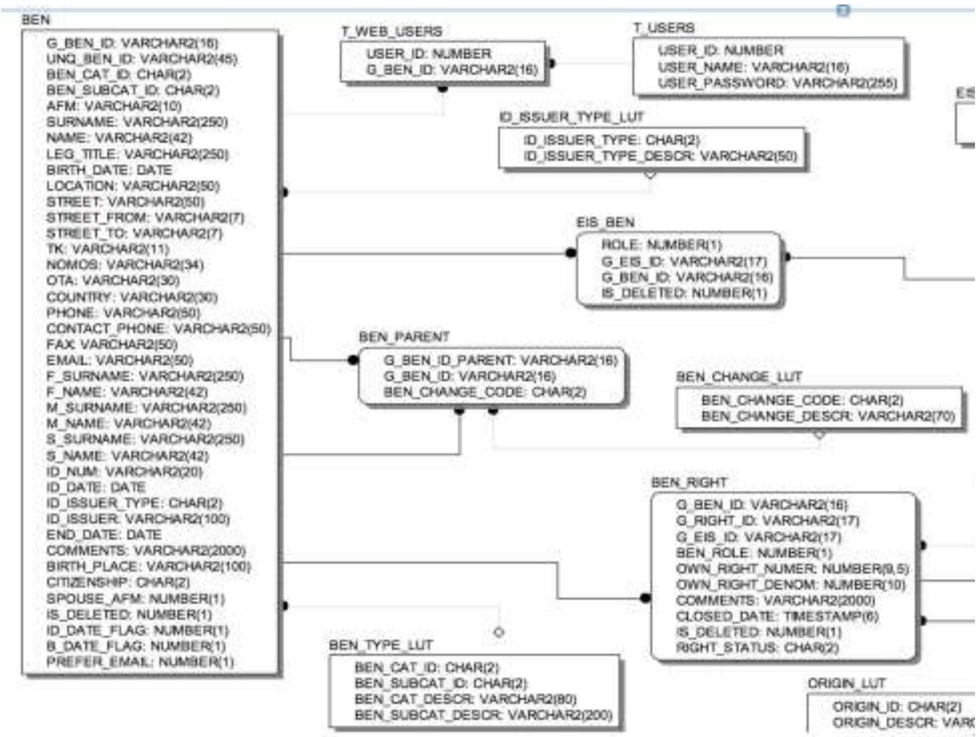


Diagram: 5.1: Table BEN and its relationships Technical specifications of HC, Annex A, 2014].

The descriptive base comprises the following classes depicted in Table 5.2:

	Table	Description
	Properties	
1.	PROP	Info about all kinds of properties, also SRPO.
2.	ADRS	Addresses of the properties
3.	PROP_ADRS	Link table for properties and addresses
4.	BLD	Info about buildings
5.	PROP_BLD	Link table for properties and buildings.
6.	VERTREL	Height info for SRPO, using ‘above’, ‘below’ or ‘inside’.
7.	FOREST	
	Stakeholders/Parties/ Owners	
8.	BEN	Physical and non-physical parties and all the stakeholders
	Rights and Documents	
9.	RIGHT	All the info about the right and also the property it refers to
10.	DOC	Documents such as deeds and titles
11.	DOC_BEN_RIGHT	Link table for the stakeholder and the right, based om the corrsponding document
12.	DOC_ISSUER	Info about those who publish the documents; ministries, notaries, etc
	Multiple standard comments	
13.	BLD_STANDARD_COMMENTS	
14.	PROP_STANDARD_COMMENTS	
15.	BEN_STANDARD_COMMENTS	
16.	RIGHT_STANDARD_COMMENTS	
17.	DOC_STANDARD_COMMENTS	
18.	BEN_PARENT	
19.	PROP_PARENT	
20.	DOC_PARENT	
21.	RIGHT_PARENT	
22.	RIGHT_ ORIGIN	
23.	DECL_AREAS	

Table 5.2:Contents of the descriptive base of the HC [Technical specifications of HC, Annex A, 2014]

5.6.4. Digital spatial database overview

The result of the spatial data processing, which is in accordance with the technical specifications issued by the National Cadastre and Mapping Agency S.A., is included in the cadastral diagrams. For urban areas the cadastral diagrams are in 1:1000 scale, where for rural areas 1:5000.

Every piece of land at the municipal level [including roads, streams, special areas etc.] is considered as cadastral parcel and spatial information is fully associated with legal and property information.

No matter the scale, all the cadastral diagrams should include the following elements:

- KAEK,
- Building ID,
- Names of streets, squares, parks, open places, archeological sites, public buildings and churches,
- Names of the rivers/ lakes/ sea,
- Toponyms, names of prefectures/ regions/ cities/ municipalities/villages,
- Boundaries of the country,
- Boundaries of the region,
- Boundaries of the municipality/village,
- Boundaries of the cadastral sector and cadastral sections,
- Boundaries of the forest areas,
- Boundaries of the special property rights objects represented as polygons,
- Special property rights objects represented as points,
- Boundaries of the mines,
- Boundaries of the reserved areas,
- Boundaries of the exclusive use areas and
- Boundaries of the cadastral parcels.

Table 5.3 presents the different levels of spatial data of the HC. Diagram: 5.1 is the entity-relationship diagram of the spatial information of the HC.

Table 5.4 is an example of the coding used by NCMA S.A. for describing the spatial data related to the cadastral parcels in the HC.

	Table	Description
1.	PST	Data for parcels
2.	ASTOTA	Data for municipality boundaries
3.	ASTTOM	Data for cadastral sectors
4.	ASTENOT	Data for cadastral sections
5.	MRT	Data for mining polygons
6.	VST	Vertical ownershipes - independent buildings
7.	EAS	Data for easement zone
8.	BLOCK_PNT	Data for measurements of points on the terrain
9.	BLD	Data for buildings
10.	ASTIK	Data for polygon of urban area
11.	EIA	Data for SPRO
12.	EIA_PNT	Data for points of SPRO
13.	ROADS	Data for roads
14.	OIK	Data for residential areas before 1923.
15.	CBOUND	Boundary of city plans
16.	FBOUND	Boundary of forest areas
17.	RBOUND	Boundary of responsibilities of mortgage offices
18.	NOMI	Land tenure
19.	POI	Points of interest
20.	POL	Parcel identification marks

Table 5.3: The classes of the spatial model of the database of the HC [Technical specifications of HC, Annex A, 2014].

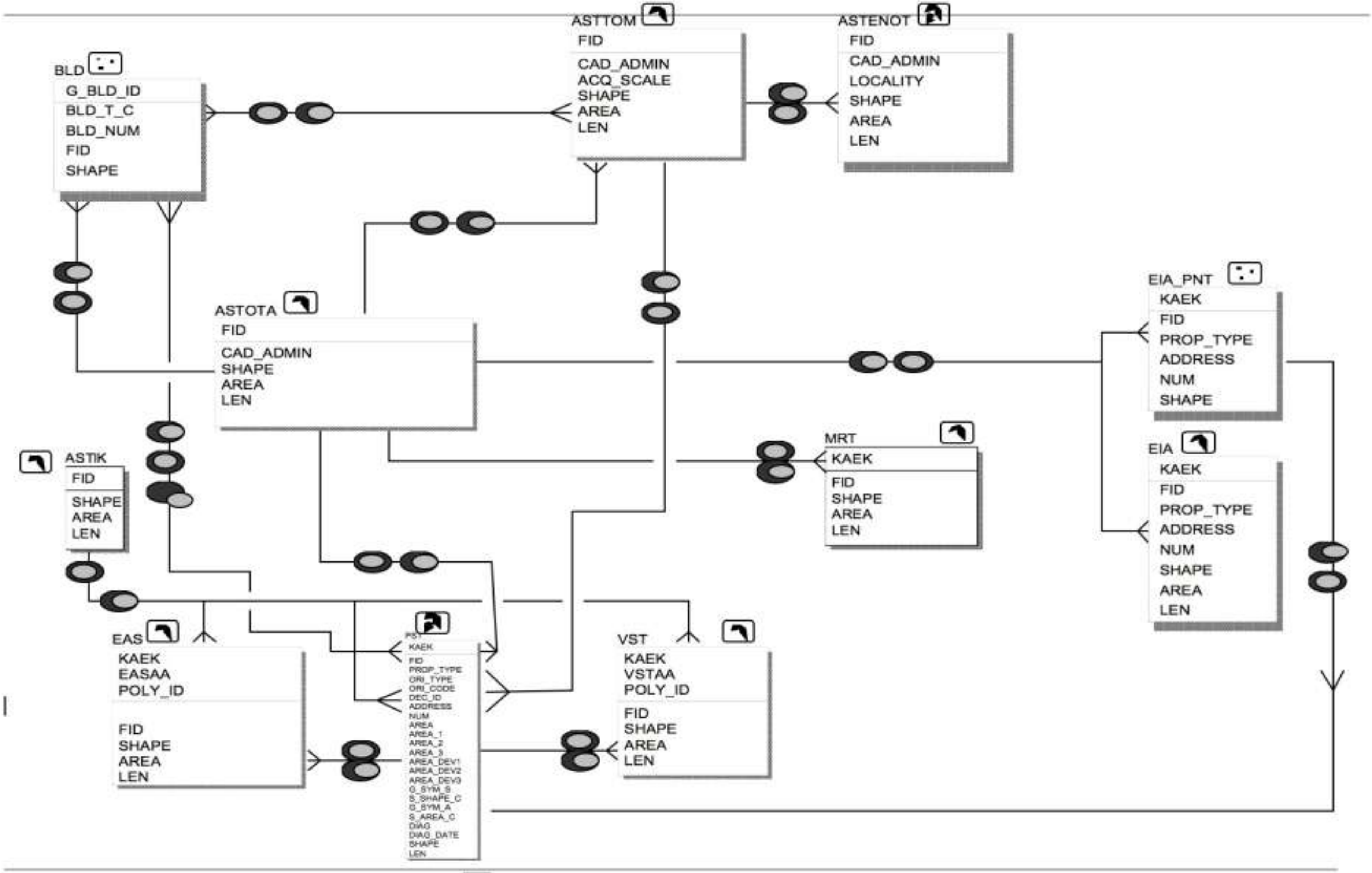


Diagram 5.2: Entity-relationship model of the HC's spatial data [Technical specifications of HC, Annex A, 201

Obect	Type	Information	PROP_TYPE	Type of the KAEK	Notes
Parcel	Polygon	Parcel polygon	0101	nnooootteeaaa	nn: Prefecture, ooo: local authorities [OTA], tt: Sector, ee: Section aaa: serial number inside the section
Mine	Polygon	Mine polygon	0601	nnoooMExxxxx	nn: Prefecture, ooo: local authorities [OTA], ME: capital greek letters xxxxx: serial number inside the local authority
Road	Polygon	Polygon	0701	nnoooEKxxxxx	nn: Prefecture, ooo: local authorities [OTA], EK: capital greek letters xxxxx: serial number inside the local authority
River	Polygon		0702		
Coastal zone	Polygon		0703		
Beach	Polygon		0704		
Lake	Polygon		0705		
Seashore	Polygon		0707		

Table 5.4: Codes of cadastral parcels [Technical specifications of HC, Annex A, 2014]

The next figure is a screenshot of a spatial query in the database of the HC, querying the database with the KAEK of a property.

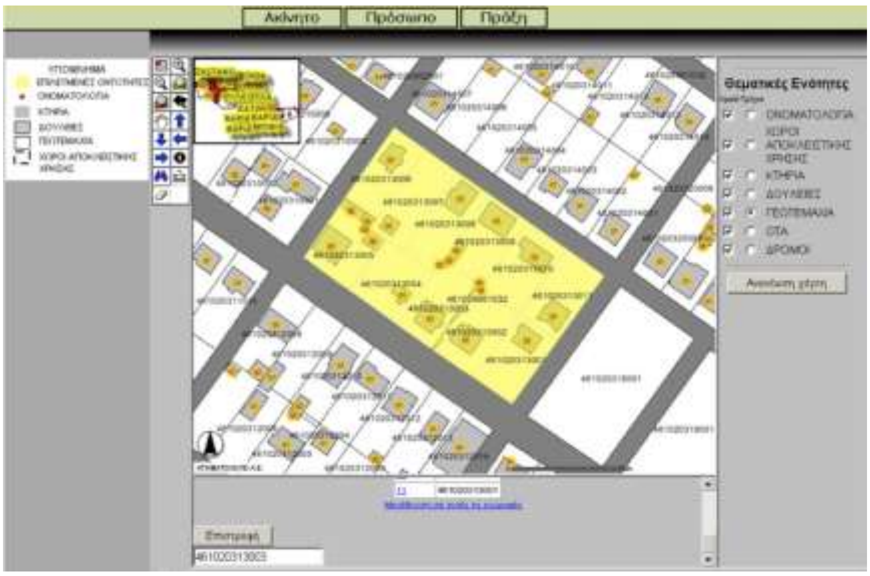


Figure 5.8: Results from spatial query using KAEK

5.7. Why registering the 3rd dimension?

It is evident that the implementation of a three-dimension cadastral model in Greece has become a necessity. Multiple initiatives towards this direction have been conducted the last decades reflecting the need to register the third dimension especially in urban built-up areas. Tsiliakou and Dimopoulou, 2011] mention the features that the Hellenic Cadastre is currently responsible for registering, as well as they underline the need for registering the third dimension.

- Land-parcels;
- Condominium;
- Vertical ownership;
- Composite vertical property;
- Special real property objects [SRPO];
- Mines.

These objects can only be portrayed by making use of the third dimension, which enables the location on, below or over the earth's surface as it is also performed in other countries. The same authors, also based on literature study, consider necessary the registration of the 3rd dimension of the following aspects:

- the intense relief of the land, resulting in complex constructions [constructions under or over bridges], multi-level buildings [overlapping private and public properties] and the entanglement of property areas for different properties [underground constructions with a surface entrance or properties with access from neighboring ones] [Papaefthymiou et al, 2004];
- multilevel constructions and mixed land uses especially in urban dense-built environment;
- the great historical value of the Greek land, on which unfortunately, many modern settlements are built on the ruins of ancient cities;
- the registration of Special Real Property Objects;
- the registration of customary property rights;
- the contradictions in Greek legislation concerning three-dimensional objects, such as condominiums;
- urban planning purposes. A 3D cadastral model would be sufficient in displaying the precise legal situation within the buildings and in detecting infringements of General Building Code (GBC);
- fiscal and real estate considerations, since the land value is high, especially in urban and commercial areas

The SRPOs are the only elements with their third dimension including at the existing cadastral model in Greece. HC does not register the evolving property reality of urban areas, characterized by an increased building density and a complicated use of space in different levels.

It is therefore necessary for the existing 2D cadastral model to provide a solution for registering and representing multilayer property activities in order to better reflect the property rights on land in Greece. The most characteristic cases that require 3D registration and representation within the Greek territory are the following:

5.7.1. Overlapping private and public properties

Due to the urbanization as well as to the traditional architecture, mostly the phenomenon with mixed land uses on overlapping properties is very common, in the Greek islands and in the cities. Public properties [e.g. infrastructures, open spaces, etc.] are sometimes entirely or partially built over, below or on with privately owned land parcels and buildings and vice versa, as depicted in the following figures:

I. Public properties below private properties

The most characteristic cases of public properties lying under private land parcels with or without constructions on them are the roads, see Figure 5.9. Additionally, in many islands privately owned constructions of upper floor, called anogia, are located over communal roads, see Figure 5.10.

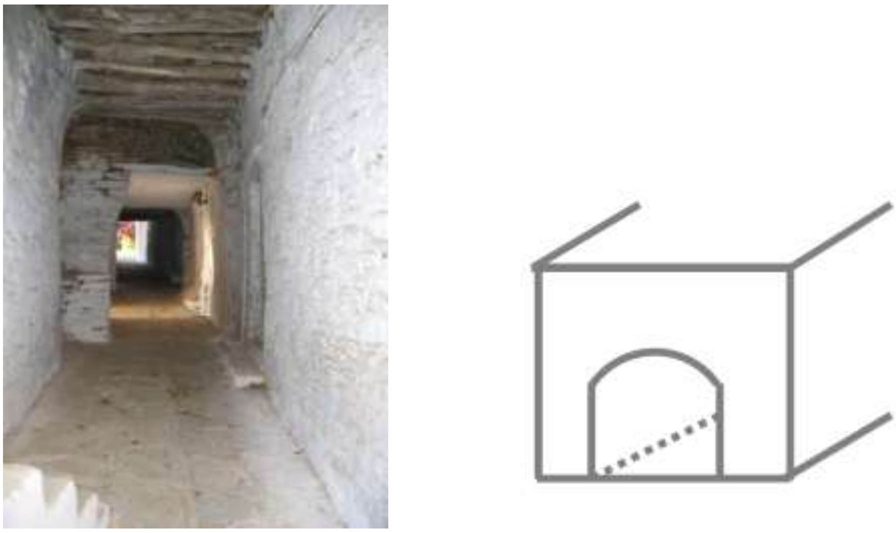


Figure 5.9: Football stadium situated over a public road [Dimopolou et al., 2006].

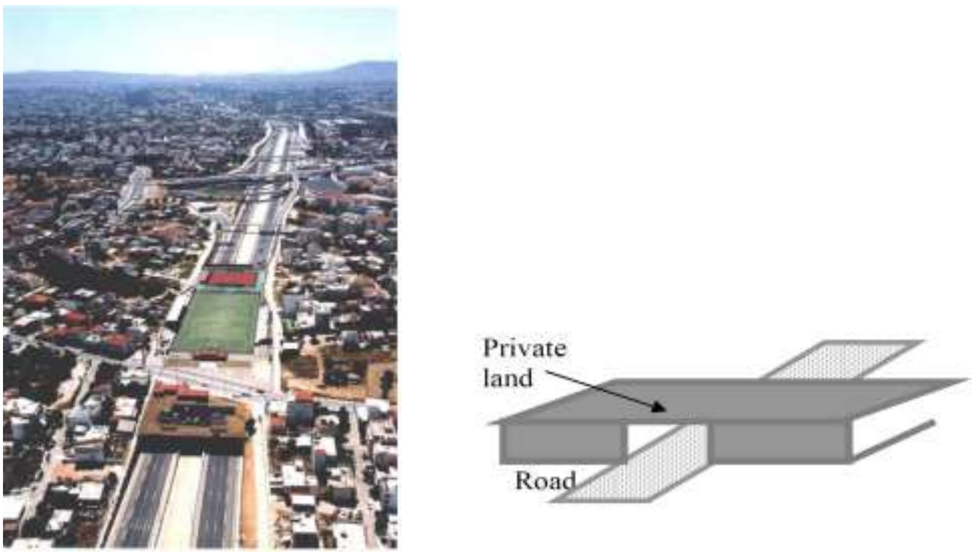


Figure 5.10: Anogia extended over a public road [Dimopolou et al., 2006].

II. <u>Public properties over private areas</u>

In urban areas with constantly increasing car density, privately owned parking places are usually located under squares or public buildings, in order to handle this problem [figure 5.11].

Figure 5.11: Overlapping parking area with public space and buildings [Dimopolou et al., 2006].

On the other hand, in rural areas the most typical cases of overlapping properties is usually mines, tunnels or cables lying below private properties, see Figure 5.12

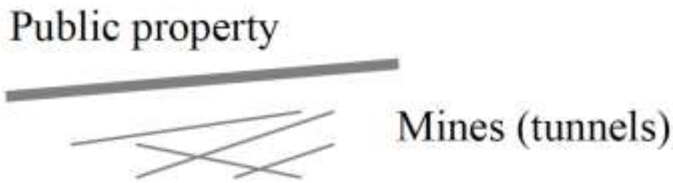


Figure 5.12: Overlapping public with private properties [Dimopolou et al., 2006].

I. <u>Infrastructure below privately owned land</u>

Subterranean networks such as gas pipelines, or telecommunication lines, mainly supplying industrial areas usually extend under the built environment.

For these utility networks, a separate registration should be considered, in relation to the surface land parcels and constructions. This 3D registration facilitates their proper and safe maintenance. An example of this case is illustrated in Figure 5.13.

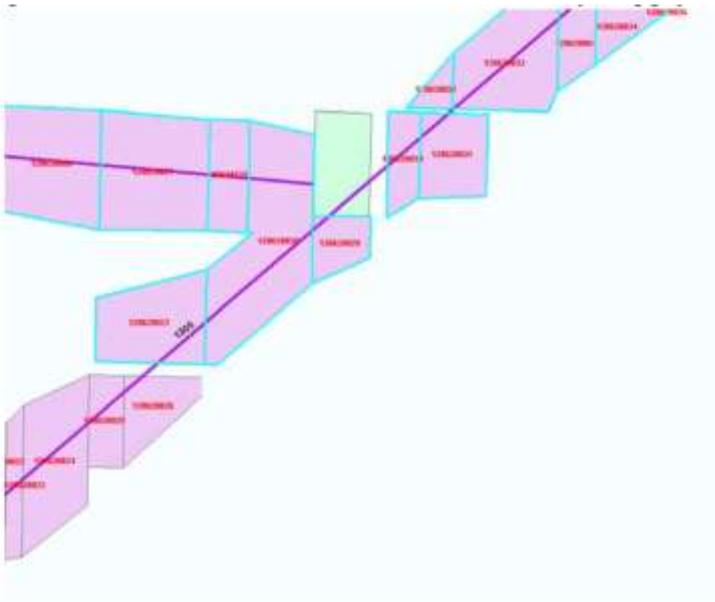


Figure 5.13: Gas pipeline network under land parcels Dimopolou et al., 2006].

5.7.2. Overlapping private properties

It is very common in several Greek Islands (e.g. in Santorini, with steep slope, where most houses are dug in the volcanic soil), that land parcels and buildings, are partially or totally overlapping to each other.

A typical example of the situations presented at the previous schemas is depicted on the following figure; where it is clear the overlapping real properties in Santorini Island.

Figure 5.14: Overlapping real properties in Santorini. [Dimopolou et al., 2006]

5.7.3. Multilevel buildings

In many complex complex constructions such as multi-use buildings,, apartments has diverse heights, different from the "*standard*" due to special constructions, such as lofts and top roofs. This results in unequal shares of privately owned space, as illustrated in the following schema. For example, the apartment on the third and fourth floor is registered as E1+E2 and double height above space, not registered, see Figure 5.15.

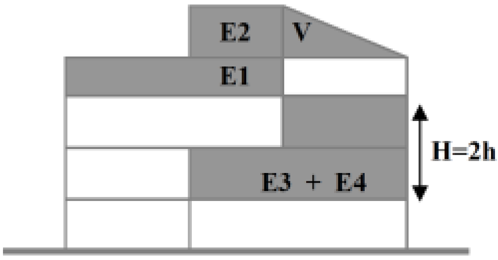


Figure 5.15: Multistory buildings [Dimopolou et al., 2006].

5.7.4. Difference between legal and physical reality

There are many cases where the physical reality represented in a map does not match with the legal as described in the deed or another administrative source. For instance, in many department stores, the floor plan's surface area is different from the one legally realized, according to the building permit. This is mostly common on ground floor stores, as illustrated in the following schema, with mezzanine [E2 in area] not requiring a cadastral registration. Dimopoluou et al., [2006] describe the situation with an example presented below. In Greece, ground floor department stores, constructed before 1985, with mezzanine area E2= ½*E1, the total area to be registered is E1, although the one realized is E1, although the one realized is E1+E2. After 1985, the new regulations oblige a cadastral registration for the total area E1+E2 realized, when λ=0 ÷1/2 and E1<E1+E2, where E2=λ*E1.

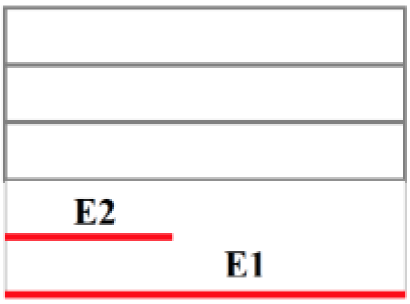


Figure 5.16: Differences in surface registered and realized [Dimopolou et al., 2006]

5.7.5. The existing cadastral situation in Greece

From all the above-mentioned, it can be concluded that the implementation of a 3D cadastral model in Greece requires the resolution of many fundamental issues underlying the current operating cadastral system. In general, the Cadastre still abstains from the implementation of digital services which will definitely boost its optimal operation.

Tsiliakou & Dimopoulou, 2011 mentioned the following fundamental principles of the current cadastral situation in Greece, underlying the existing limitations:

- **For the SRPOs:** SRPOs is a special class related to a plethora of objects, which are characterized by multiple and complex topological relations They the only feature with a 3D tag in the existing cadastral model. However, according to the HC project, they are manipulated not as spatial information but as descriptive. This is done with the following approach. During the cadastral survey, the surveyors are forced to attach a relational matrix to the deliverables of the survey, which would include the description of these objects in a structured descriptive manner using words as "*below*" or "*above*". According to the technical specifications of the HC the information that should be registered for the SRPOs are:
    - The KAEK,
    - The FID; an identifier for each SRPO,
    - The PROP_TYPE, the type of the property [the values that can be registered are given in a separate table],
    - The address of the parcel in front of the SRPO and
    - The shape-geometry of the SRPO.
- **For the buildings: The spatial database contains information regarding** buildings, however there informaton for the outlines and/or the footprints of them are not currently represented. However, the existing spatial data model includes an entity for the buildings, allowing their future registration.
- **Aspects that should be represented in 3D:** Buildings' floors in the case of horizontal ownership are only registered as an attribute today, which is not the optimal way to be described. Additionally, the source documents do not contain floor plans of the apartments. Consequently, there is no further height information registered in the system apart from the buildings' code, the floor and the property's KAEK.
- **Maintenance and update of spatial data:** The current ownership status is not efficiently registered in the cadastral system, while the link between the descriptive and the spatial data is limited to the KAEK.
- **Cooperation between the institutions responsible for the geo-information:** This is one of the fundamental problems of the existing system. Currently, the communication and the exchange of information between all the responsible organizations that collect, produce, store, maintain and visualize geo-information is not open. A lot of bureaucratic procedures is needed in order to exchange spatial and no-spatial information between those organizations. This leads to problems with the update of the database, loss of information, inaccuracies and time wasting.

According to the same authors, the main drawback of the current Hellenic data model is that it mostly manipulates the legal information on properties, excluding the representation of the spatial aspect of RRRs as the information needed does not exist.

5.8. Conclusions

The Hellenic Cadastre (HC) is a unified and constantly updated system of information that records the legal, technical and other additional details about real estate properties and the rights on them. Although the project started its operation in 1995 and is in progress for 20 years, the results in some regions are quite disappointing concerning progress and efficiency.

The need for 3D registrations and representation in Greece is vital concerning special cases like the multilevel constructions, the overlapping properties and the SPROs. A successful 3D Cadastre for Greece will constitute a unique tool, a level for sustainable development in urban and land planning and in every aspect of technical, financial, social and legal issues of everyday life. It can also be used as a means for political decisions and pressure, which is nowadays a key challenge for the Greek reality.

The characteristic cases, which require 3D registration are presented in this chapter and is concluded that the hybrid model seems to be the best solution for the Greek case.

The key issue and main drawback concerning the development of the Greek Cadastre is basically legal. It is quite obvious that Greek legislation contains contradictory laws on property rights, which is rather confusing. Therefore there is a need to perform relevant adjustments in order to overcome this situation.

The limitations and problems of the existing situation do not regard the producers and users of the cadastral system nor from the expertise they have developed. The problem is focused on the insufficiency and inactivity of the existing structures of the public administration to adapt to new global tendencies and, of course, their reluctance in supporting the scientific personnel of HC in order to enhance numerous aspects of the Greek reality. These problems are further discussed in Tsiliakou and Dimopoulou, 2011.

However, Greece has made a first step forward when the Ktimatologio S.A. and HEMCO were merged into one unique organization, the NCMA S.A., like the Kadaster in the Netherlands, the Cadastral Office in Belgium, etc. Those organizations are responsible for both the collection of the geographical information and the registration of the legal rights attached on them. Additionally, during the cadastral surveys a special adjudication procedure is been followed and parallel infrastructure projects are carried in order to facilitate the progress of the project.

To sum up, the third dimension needs to be incorporated into (some) cadastral registrations; however, several modifications to the actual property rights' registration procedure are required. Therefore, it is vital to consider fundamental issues of the operating HC, such as the fact that the outlines of any construction are not represented on the cadastral map.

Part III

Proposed Model

6. Proposed Model for land management in Greece

Despite its small surface area, Greece is endowed with a particular rich and diversified natural environment; with singular geomorphology and intense contrasts [http://www.visitgreece.gr/en/nature]. It is a country with mountainous and rocky terrain and about 20% of the country is made up of islands. All those diversities conclude to a complex scenery, with big differences in altitude; which should be registered and managed into a coherent and unified system. Moreover, the rights, restrictions and responsibilities attached to that scenery, the activities developed, the responsible parties, as well as the difficulty to represent the outline of it need to be described explicitly. Consequently, there is a need for creating a model, emphasizing on the third dimension where all the different characteristics will be described.

This chapter is dealt with the development of a conceptual model in UML that deals with the registration and management of objects and spaces related to 3D cadastre system. The model is created based on the implementation of ISO 19152, LADM classes by conforming to the existing situation.

In particular, this chapter proposes a comprehensive Land Administration Domain Model [ISO 19152] country profile for 2D and 3D cadastral registration system for Greece. The proposed Greek country profile is partly based on the existing spatial [including survey] and administrative registration systems, and partly based on new developments inspired by the LADM standard. Within the country profile, an attempt is made to cover all Greek land administration related information, which are maintained by different organizations.

The proposed model has a broader perspective than the current data model used by National Cadastre and Mapping Agency S.A. What makes the development of this Greek country profile unique is the support for a wide range of parties as well as spatial units. Each of them has different roles and requirements. The country profile includes the content of the various code lists, which are important aspect of standardization and unique for each country. Code lists are used to describe a more open and flexible enumeration values and are useful for expressing a long and potentially extensible, list of potential values.

Several novel aspects for Greek land administration are introduced, such as: 3D representations, full version management, explicit linking of all land administration information and source documents in digital form and possibility to group multiple spatial units with the same characteristics, legal framework and visualization demands, using the *LA_Level* concept.

The country profile helps to establish a national SDI enabling meaningful exchange of information between different organizations distributed along the Greek territory. The fact that LADM is an international standard and also supports international exchange of information, as part of the Global SDI [from now, GSDI].

6.1. Towards a multipurpose 3D Cadastre

In recent years, a 2D cadastre registration system is being developed in Greece. The need for 3D in many cases; see 5.7; in served by adding the third dimension only as textual information, or by setting topological rules. In this chapter a 3D model is propose for Greece; covering a broader perspective than the National Cadastre and Mapping Agency S.A..

The current cadastral system, still do not support three-dimensional capability. Therefore, a good organization is very important in order to achieve an excellent and reliable cadastre registration system.

However, due to historical constraints, it seems quite difficult to realize this unless there is full cooperation from various legal bodies, technical organizations and other land-related government agencies and private sector participants in Greece. A multipurpose 3D cadastre [from now, MPC] can be defined as an integrated land information system containing legal [e.g. tenure and ownership], planning [e.g. land use zoning], revenue [e.g. land value, assessment and premium] and physical [e.g. cadastre] information.

Therefore, the Greek multipurpose 3D cadastre should contain all information about administrative records, tenure, value and sale and purchases records, base maps, cadastral and survey boundaries, categories of land use, streets addresses, census utilities etc. It has the potential to support spatial enabled government, private sectors and society by expanding the process of organization, management and visualization, of useful land information. In brief, there are many advantages for implementing a multipurpose 3D cadastre. It is especially useful for property inventory, project implementation and monitoring, utility management, population estimates, school management, census mapping and urban and rural development [Choon & Seng, 2013].

A well- structured multipurpose cadastre will be of benefit to the government, different level of administrative division [municipality, region, etc.], private companies, public agencies, academia and the citizens themselves. It will serve as the main source, which will contain all available spatial and semantic information concerning land and marine parcels. Visualization of these parcels in 3D will further enhance the nature of the multipurpose cadastre and introduce the concept of 3D modeling.

As an integrated land information system it can exhibit data on RRRs and all encumbrances associated with the parcel. This will promote transparency and wealth creation in the land market [Rahman A., et al., 2012]. Knowing who owns, what and the corresponding associations with other RRRs will strengthen property ownership, project implementation and monitoring.

One significant problem in Greece today is that there are differences between the physical and the legal reality of the parcels. The parcel with its boundaries and the RRRs associated to it as described in the deed, is not exactly the same with the "real" parcel and the RRRs attached to it. It is clear that only by introducing an international standard into the Greek land administration system cannot solve this problem. However, it is an important first step to best organize all the information.

Gathering all the information related to the land and marine parcels, properties with archeological interest, network utilities, mines, Special Property Right Objects and the planning zones would create a unified and multipurpose LIS for Greece. It is difficult to have such spatial and semantic information with their interrelations together as there are many factors that affect them; but this will lead to a transparent and coherent LIS.

As a result, a 3D multipurpose cadastre for Greece should have the following components:

- Land parcels [2D & 3D parcels];
- Properties with archeological interest [immovable monument, archeological site, area of cultural environment, etc.];
- Mines;
- Utility networks [water, telecommunications, etc.];
- Special property right objects [anogia, katogia, etc.];
- Marine parcels;

From the issues as listed above [bullets] not all need 3D registration and visualization. Each category will be further explained at the 6.4.3.

Monitoring of the existing situation as well as planning for further development will benefit from such a system. Moreover, the tax system can be more efficient and all the transactions more transparent. A multipurpose cadastre including all the above-mentioned information can serve as a basis for all the organizations in Greece solving the problem of duplicates and errors.

Figure 6.1 illustrates the general view and the components of the proposed MPC in Malaysia; where there are many different kinds of spatial units.

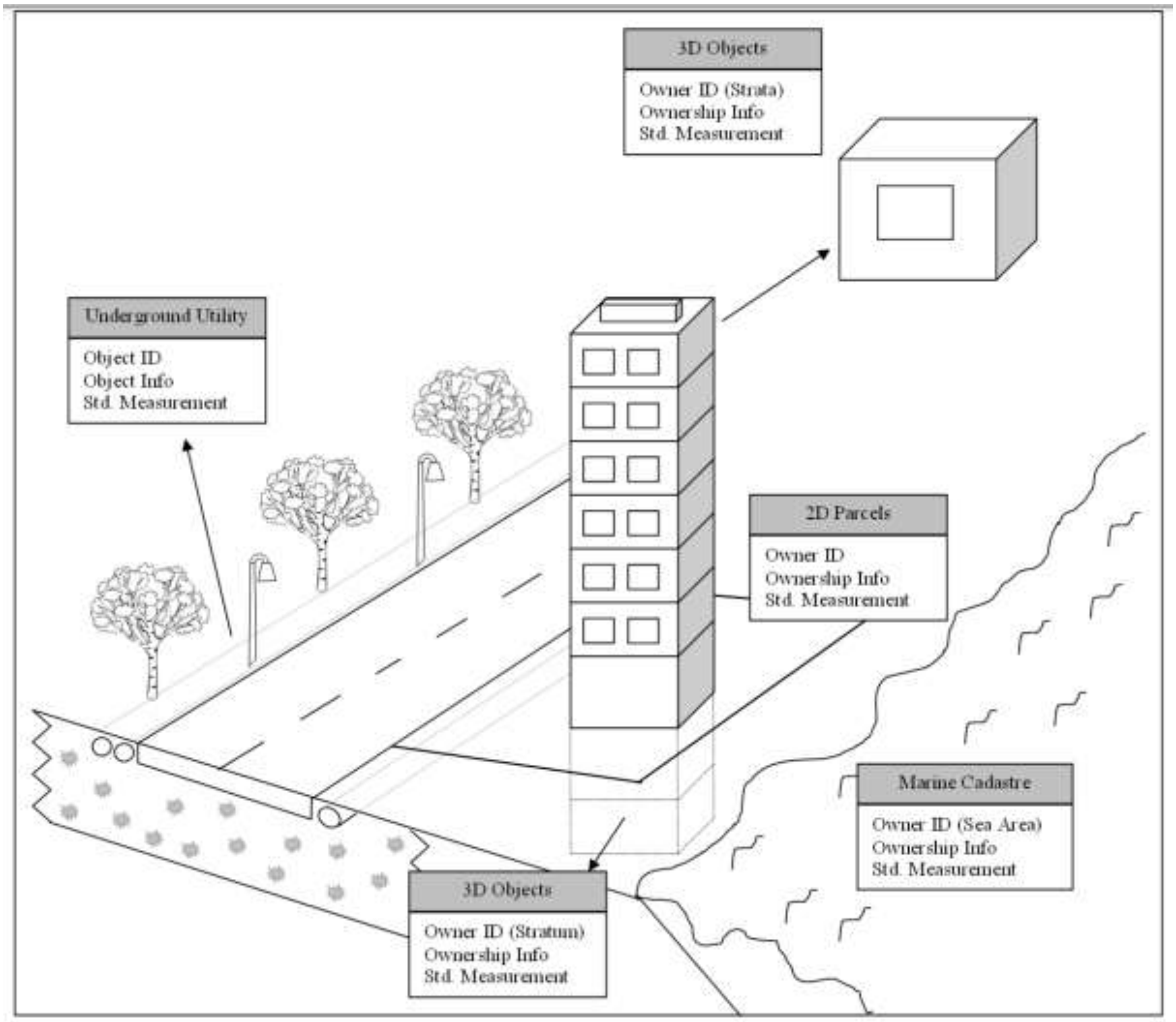


Figure 6.1: The anticipated schematic diagrammatic diagram of MPC [Rahman A., et al., 2011].

6.2. Motivations to apply ISO 19152

The dynamic features of spatial information, together with the continuous need for its representation through geographic information technologies are the two basic reasons for the adoption of international standards in the core structure of modern cadastral systems [Dimopoulou and Gogolou, 2013]. Additionally, domain specific standardization is needed to capture the semantics of land administration domain on top of the agreed foundation of basic standards for geometry, temporal aspects, metadata, as well as measurements from the field.

As the Hellenic Cadastre is still being implemented, the use of standards for land administration and management could serve its harmonization with the international practices. Moreover, a standard is required to facilitate the communication between professionals in order to develop, implement and maintain systems in a more efficient way.

The international state of the art shows that innovative models have been created in order to achieve effectiveness and interoperability between different systems. Sufficiency of administrative and spatial representation of land properties could also be achieved if common standards are used.

The core model provided by the Land Administration Domain Model [LADM]; see sub-chapter 1.4.5.; is an excellent basis for this purpose. The LADM, as an ISO standard seems suitable for the detailed administrative and spatial representation exported by the properties that include various spatial unit types and party members. This is due to the fact that the core model provided includes a wide range of classes and possibilities of linking with external information concerning the ownership status of the above properties. In this way, a modern geospatial infrastructure could be created for the best management of the geographical information in Greece, combining not just classic GIS platforms, but also descriptive administrative information for the various RRRs attached on the parcels in a standardized structure as well.

ICO/TC211, 2012; Lemmen et al., 2010 state: "*The LADM is a conceptual model, and not a data product specification…The purpose of LADM is not to replace existing systems, but rather to provide a formal language to describe them, so that the similarities and differences can be better understood. It is a descriptive standard not a prescriptive standard. Land administration is a large field; the focus of this International Standard is on that part of land administration this is interested in RRRs affecting land or water and the geometrical components. The LADM provides a reference model…*"

According to Tjia and Coetzee [2012b], earlier studies upon which the LADM is based include the Cadastre 2014. The Cadastre 2014 provided that the modern cadastral systems need to move away from the traditional concept of cadastre to a more integrated cadastral modeling and legal land objects. Also, Lemmen et al. [2011] note that the implementation of LADM can be performed in a flexible way. In other word, the standard can be extended and adapted to local situations, which excluded the legal implications that interfere with national land administration laws.

Furthermore, external links to other databases, e.g. addresses, are included. LADM can be used for as a basis for the design of Land Administration Systems. It facilitates appropriate system development and, in addition, it forms the basis for communication between different systems in different organizations and the application design can be based on GIS and database technology. When using standards, information can be exchanged in heterogeneous (commercial and open source) and distributed environments.

The model has been introduced for land registration purposes. The development of it is designed as a base for various land registration practice in different countries. Two important goals of this model as listed in [van Oosterom et. al 2006]:

- To avoid reinventing and re-implementing the same functionality over and over again, but provide an extensible basis for efficient and effective cadastral system development based on a model driven architecture [MDA], and
- To enable involved parties, both within one country and between different countries, to communicate based on the shared ontology implied by the model.

The term "3D cadastre" can be interpreted in many ways ranging from a full 3D cadastre supporting volume parcels, to traditional cadastres in which limited information is maintained on 3D situations. Integrated 2D and 3D parcels in hybrid cadastre, as proposed by Stoter [2004], can be used for the implementation of 3D cadastre in Greece, based on LADM. The concept of hybrid cadastre is to preserve the current 2D registration and add the 3D component in the registration system.

The classical cadastres concepts as "parcel" and "boundary" have been extended to include spatial representation of multidimensional objects: 3D and 2D/3D combined and are embedded in the LADM base model. An integrated 3D cadastre model looks on how to add 3D component in the current cadastre data model and make information interoperable between the two involved organizations. 3D cadastre objects, e.g. apartment buildings are real property that being built on the 2D land parcel. Text based, sketch based, point based, line-based, polygon based, or topological based representations of spatial units [parcels] are possible. Spatial units may have a 3D representation, and a provision is made for a mixture of 2D and 3D spatial units to co-exist [ISO 19152, 2012].

LADM also covers land registration and cadastre in a broad sense [Lemmen and van Oosterom, 2011]. This is aimed at improving interoperability between cadastral or related information systems, thus improving exchange of land information between local, national and international organizations and information society [Tjia and Coetzee, 2012a].

Recent works suggest that the utilization of LADM for cadastral domain is significant as mentioned by several researchers: Lemmen [2012], Van Oosterom et al [2011], Pouliot [2011] and Hespanha [2012]. Zulkifli et al, 2014, state many different reasons to specifically adopt the ISO 19152 LADM. It:

- contains the collective experience of experts from many countries [in ISO and FIG];
- took long time to develop in the FIG/ISO project team, but LADM is based on consensus and now adopted by ISO [and CEN];
- allows meaningful data exchange: within country, SDI-setting, and between countries;
- covers complete land administration spectrum: survey, cadastral maps, rights, restrictions, responsibilities, mortgages, persons [individuals of groups], etc.;
- allows integrated 2D and 3D representation of spatial units;
- supports both formal and informal RRRs; and
- link essential land information data to source documents, both spatial [survey] and legal [title, deed].

Realistically, LADM provides a flexible abstract model, which can be used as basis for many cadastral systems all over the world. However, every system does need smaller or larger upgrades and maintenances; and they consider becoming LADM compliant. More and more papers and presentations each year mention many good reasons to consider LADM; e.g. Kalantari et al., 2013.

Application of LADM brings the following benefits:

- international compliance;
- cross jurisdictional data exchange;
- upgrading or new versions for existing systems;
- existing institutions ['do fit in well'];
- semantic compliance [definition of key concepts];
- structural compliance [agreed model patterns];
- feedback and improvements [during standard development, but also needed afterwards]; and
- capacity building [LADM included in various curriculums].

Thompson [2013] concluded that the LADM also provides an excellent growth path: from text, sketch and point parcels to full topology and 3D support [and same range of options available in administrative side of the model. This is also the reason for UN-HABITAT (STDM) and FAO to use the standard.

For all those reasons many countries have already introduced and implemented LADM; e.g. The Netherlands [Stoter et al., The phased 3D Cadastre implementation in the Netherlands, 2012; ISO 19152, 2012], Malaysia [Zulkifli et al, Towards Malaysian LADM country profile for 2D and 3D Cadastral registration system, 2014; Zulkifli A., et al, Developing 2D and 3D cadastral registration systems based on LADM: Ilustrated with Malaysian Cases, 2013], Israel [Felus Y. et al, Steps towards 3D Cadastre and ISO 19152 [LADM] in Israel, 2014], Indonesia [Budisusanto Y., ET AL, LADM implementation prototype fir 3D Cadastre Information System of Multi-Level apartment in Indonesia, 2013], Cyprus [Elia E. et al, The land administration domain model [LADM] as the reference model for the Cyprus land information system [CLIS], 2011], Queensland, Australia [ISO 19152, 2012], Shenzen; China [Guo R. et al, A multi-jurisdiction case study of 3D Cadastre in Shenzen, China as experiment using LADM., 2011], etc. For further analysis of the countries profiles see 4.

6.3. Matching of LADM and Hellenic Cadastre Data Model

The Hellenic Cadastre is a unified and constantly updated system of information, which records the legal, technical and other additional details about real estate properties and the rights on them; this information is kept under the responsibility and guarantee of the State and in particular, of the National Cadastre and Mapping Agency S.A..

The HC's descriptive and spatial information is organized in a property-centered base. The Hellenic Cadastre Data Model is not based on international standards but has been developed in order to serve the needs of the Greek society. As a result, it cannot be used as basis for building a National SDI in Greece in order to enable interoperability and data exchange between the different organizations and institutions but also between different countries.

For that reason, the proposed model based on the international LADM standard is considered as a step tackling the previous shortcomings. The flexibility between the two cadastral systems could be achieved by expressing their core model with terms of LADM. The process of standardization could create connectivity and interoperable possibilities for the best management in Greece. Furthermore, according to Gogolou, [2013]; Kalogianni [2012] the integration of a unique system that would include all registrations concerning properties could be completed with the following of international practices and the adaptation of recognized standards.

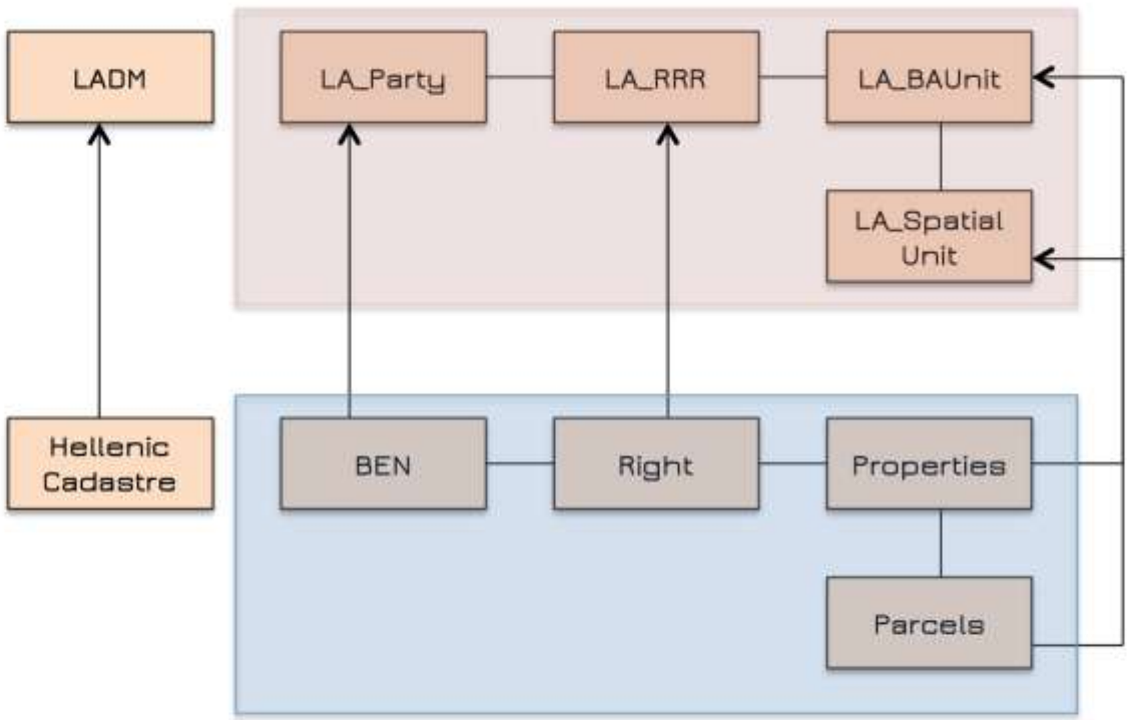


Diagram 6.1: Matching of the HC Data Model and LADM classes [Gogolou, 2013]

In HC the ownership of a property could be spatially represented with the entity of Parcel (LA_SpatialUnit) that belongs to public or private owners (LA_Party).

The rights, restrictions and responsibilities existing (LA_RRR) are related to the use of land together with the protection of the areas and the detailed administrative information for them is included (LA_BAUnit).

The structure of the HC is shown in a general view for the needs of the matching. The entities represent all the beneficiaries (LA_Party) that own properties in the Greek territory together with their spatial representation (LA_SpatialUnit) and the rights or weights exercised on them (LA_RRR) with the registration of their administrative information (LA_BAUnit).

Beneficiaries of the HC correspond to LA_Party; Rights of the HC to LA_RRR; Propertied of the HC to LA_BAUnit and Cadastral Parcel to LA_SpatialUnit.

Diagram 6.1 describes the matching of the corresponding entities between LADM and the existing HC data model.

6.3.1. Existing work based in LADM in Greece

The last three years LADM has been used as basis for the creation of conceptual models in Greece in a research level. Kalogianni, 2012 introduced the model to the Hellenic reality creating a model for the management of the Greek public property. Gogolou 2013 created a conceptual model for the archeological cadastre in Greece and Athanasio, 2014 proposed a conceptual model for the marine cadastre. Therefore, Psomadaki, 2014 proposed a model for the Harmonization of the Hellenic Cadastre with international standards including LADM and INSPIRE.

However, none of those models attempted to cover a scope broader than the scope of HC on the domain of land administration. The proposed model combines the previous knowledge and based on the previous proposed models it attempts to create a model for a multipurpose cadastre in Greece.

For that reason, the concept of levels was used. According to ISO 19152, 2012, a level is defined as a set of spatial units with a geometric and/or topological and/or thematic coherence. By implementing this concept in Greece, different groups of spatial units have been created with regards to its thematic and sometime geometric characteristics in order to best organize them. This will be further analyzed in 6.4.3.

6.4. Conceptual model

As mentioned in 3.3.4 all the classes of LADM, apart from the abstract class, LA_Source and the two subclasses: LA_AdministrativeSource and LA_SpatialSource; are subclasses of the class VersionedObject. As source documents cannot change, only new source document can be inserted in the system, they are not versioned.

In ISO 19152, 2012 is mentioned that LADM via the class VersionedObject covers the state based modeling. This means that the states (results) are modeled explicitly: every object is assigned at least two dates or times which indicate the time interval during which the object is recorded in the system as actual version. Through the comparison of two successive states it is possible to reconstruct what happened as a result of one specific event.

The temporal aspect is inherited from class VersionedObject with its attributes beginLifespanVersion and endLifespanVersion. The class LA_RRR has an additional temporal attribute called timeSpec, which is capable of handling other temporal representations, such as a recurring pattern (every month; every year; etc.)

At the rest of this sub-chapter the packages of the proposed model are analyzed together with the external classes and their code list. Emphasis is given at the different levels that have been created for the best management of the properties in Greece. "GR_" is the prefix for the Greek country profile proposed, covering both the spatial and the administrative data modeling.

Note that there are several abstract classes in the proposed model indicated in Italics. These classes are only introduced to support the conceptual model, representing shared attributes and structures, and they get no instances. This means that they don't get any corresponding table in the database implementation. Based on spatial and non-spatial data modeling, several classes have code lists.

All the UML models are created in EA (Enterprise Architecture) software, which can be used to set up and create databases.

Diagram 6.2 illustrates an overview of the non-spatial part of the proposed model and its external classes in UML diagrams.

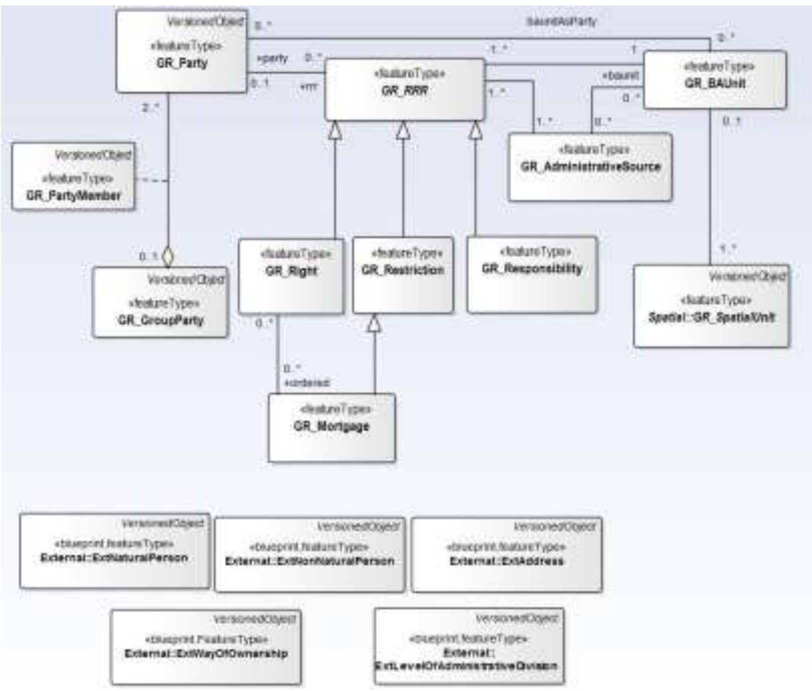


Diagram 6.2: Non-spatial modeling overview.

6.4.1. Party Package

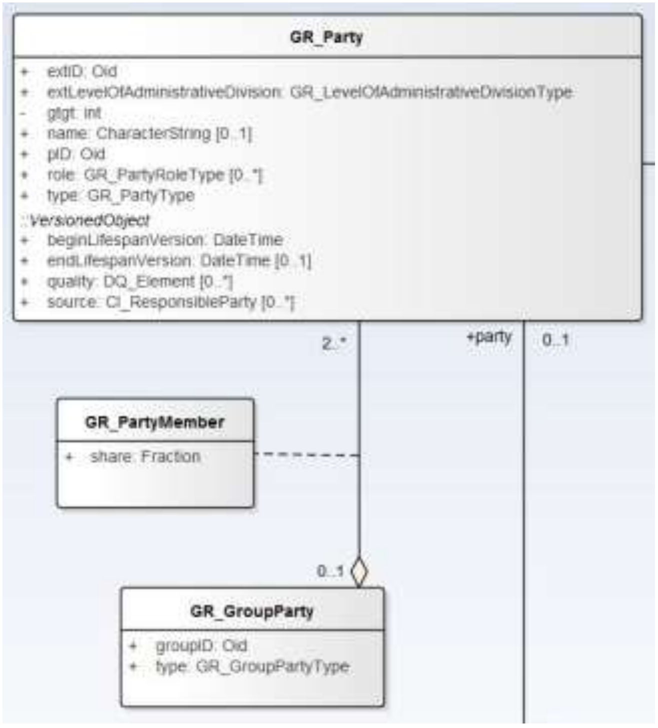
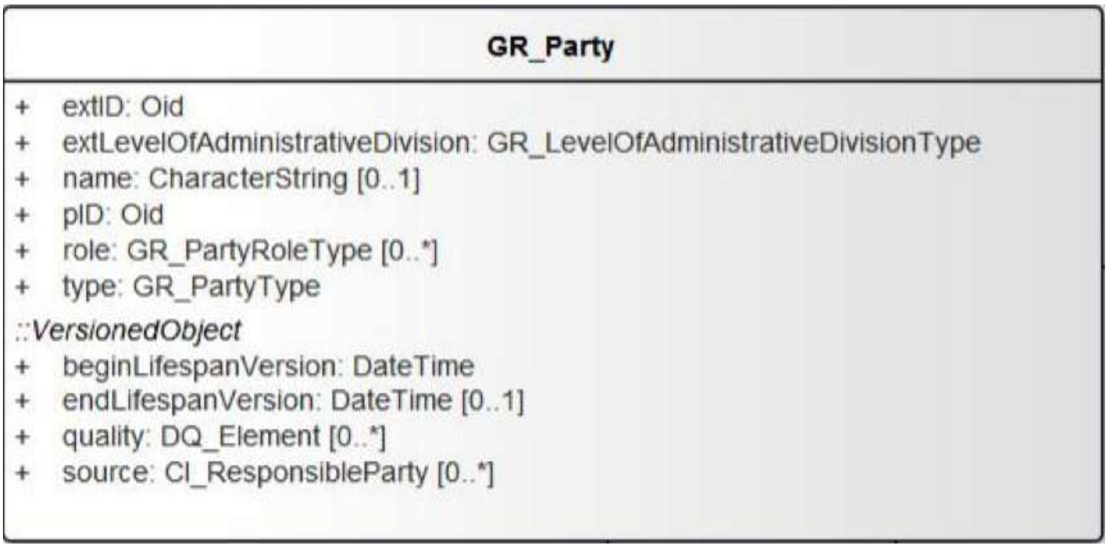


Diagram 6.3: Content of GR_PartyPackage and associations with other basic classes.

II. GR_Party class

The class GR_Party is the main class of the Party Package. As party is considered as a person or organization that plays a role in a transaction [Lemmen, 2012]. LA_Party is also associated to LA_BAUnit, to cater for the fact that a basic administrative unit can be a part (e.g. a basic administrative unit holding an easement on another basic administrative unit).



◊ <u>Code list GR_PartyType</u>

GR_PartyType

+ P01 - Group
+ P02 - Natural person
+ P03 -Non natural person
+ P04 - Basic Administrative Unit
+ P05 - Greek Public State
+ P06 - Foreign State
+ P07 - European Union
+ P08 - Unknown

◊ <u>Code list GR_PartyRoleType</u>

The different roles if a party are described by the NCMA S.A., the Archeological Cadastre and other organizations involved in the transactions. For instance, there are different levels of courts; legislative authority [President of the Hellenic Republic; Greek Parliament; the former King of Greece].

GR_PartyRoleType

+ PR01 - Lawyer
+ PR02 - Bank
+ PR03 - Notary
+ PR04 - Citizen
+ PR05 - Institution
+ PR06 - Tax Office
+ PR07 - Insurance orgnization
+ PR08 - Church
+ PR09 - Surveyor
+ PR10 - Metropolis
+ PR11 - Parish
+ PR12 - Court
+ PR13 - Court of Appeal
+ PR14 - High Court
+ PR15 - State Council
+ PR16 - Legislative Authority
+ PR17 - Expropriation Committee
+ PR18 - Ministry
+ PR19 - Local Authority
+ PR20 - Urban Planning Authority
+ PR21 - General Secretary of the region
+ PR22 - To be filled

III. GR_GroupParty class

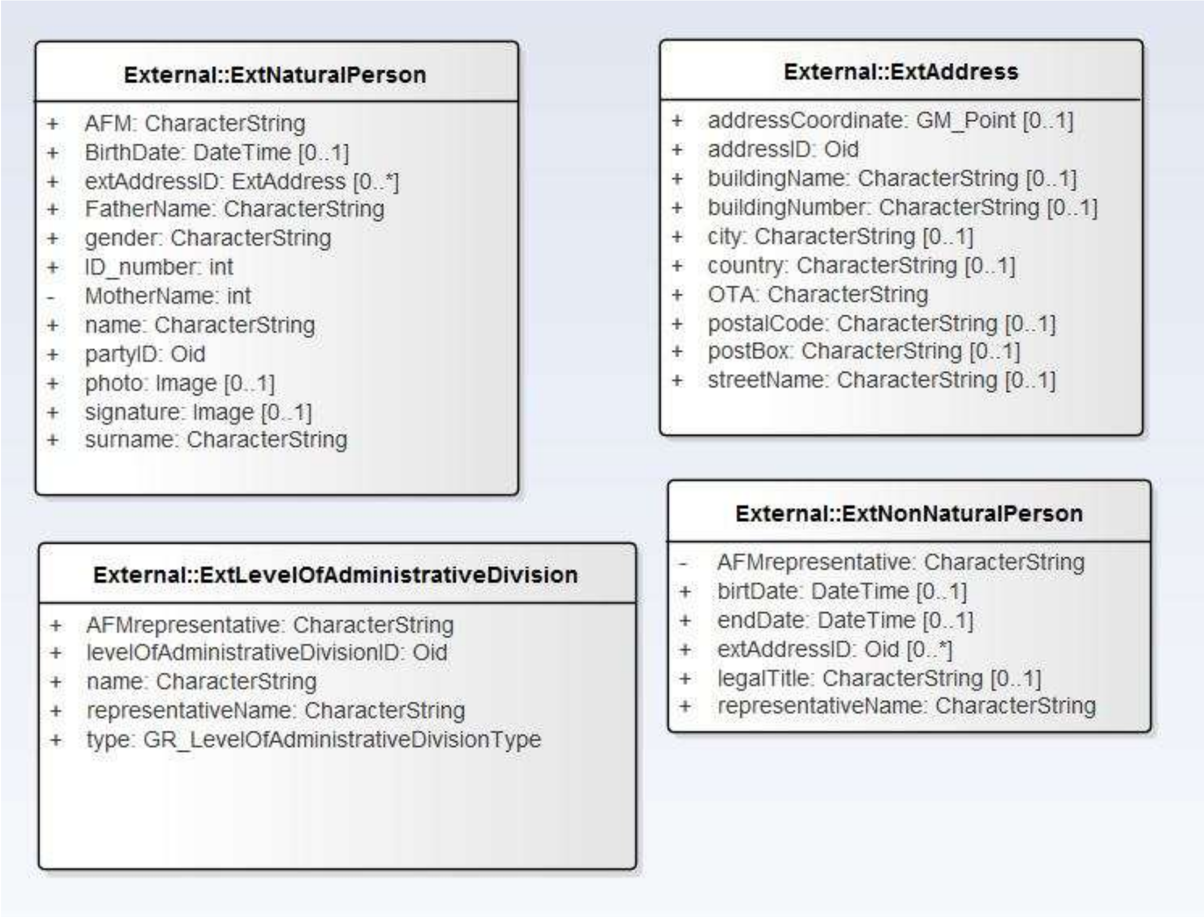
A group party is any member of parties, forming together a distinct entity; e.g. a village community. A party member is a party registered and identified as a constituent of a group party [Lemmen, 2012]. For the proposed model a group party can be a group of administrative units or a Consortium.

◊ **Code list GR_GroupPartyType**

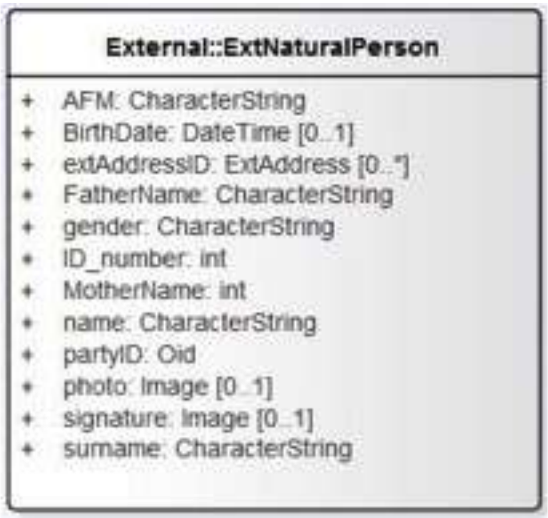
IV. Party Package External Classes

External classes have been created for Parties. This is in support of implementations on information infrastructures. The idea is to use only authentic data in such information infrastructures. The external classes indicate what data contents LADM is expecting from external sources.

Four external classes have been created for Parties; for natural persons, non-natural persons, the level of administrative division and the addresses as shown at the next figure. The first two external classes can be a link to a population register, or to a chamber of commerce with a company register or to external databases with certified parties with a role in land transaction [Lemmen, 2012]. Class External Address is a class for external registration of addresses. As proposed in ISO 19152, 2012, the INSPIRE address specification may also be used [INSPIRE, 2010] or an ISO standard [e.g. ISO 19160]; which includes addressing terminology, conceptual models, quality management and rendering addresses on postal items, maps, etc.]. Last but not least, the class External level of administrative division is introduced because the different types of spatial units that have been introduced at the spatial package are linked with a number of different stakeholders and parties. For that reason, it is considered that the separation of different administrative levels according to Kallikratis plan in Greece will facilitate the organization and separation of the party package. The identifier of a party in an external registration [extPID] is an attribute of GR_Party class.

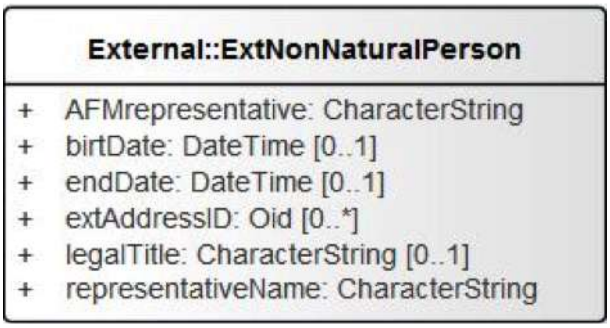


External Natural Person

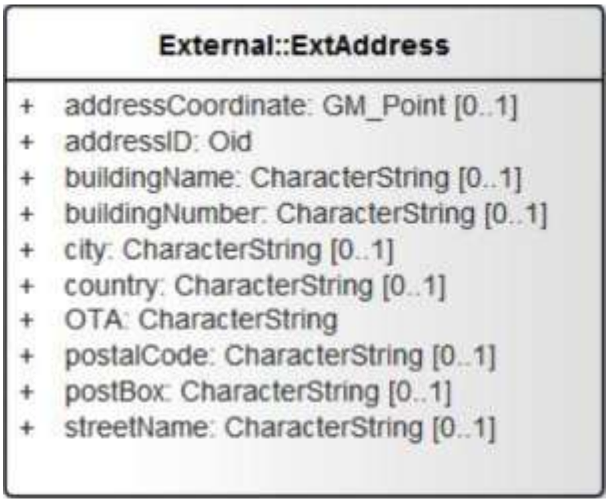


AFM is the unique code for each citizen in Greece related to his/her tax obligations. Apart form the ID number that is used in order to verify the uniqueness of a party, the AFM is introduced here, as all the parties should always mention this number in their transactions.

- External Non Natural Person



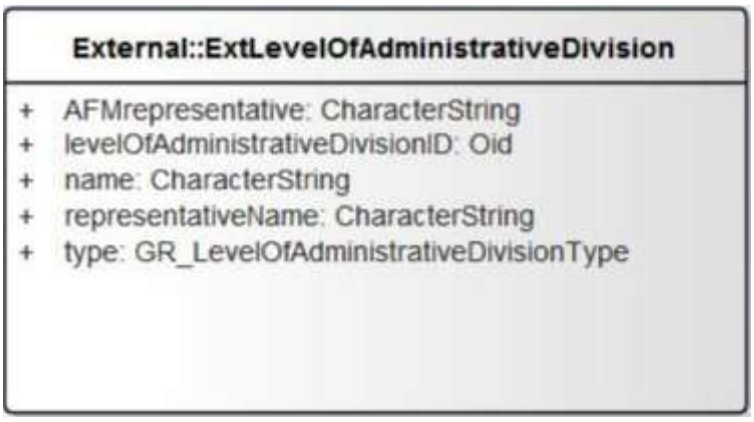
- External Address



The attribute OTA defines the local authority where the address belongs.

External level of administrative division

According to Kallikratis plan, the reorganization of regional and local government in Greece held in 2011, there are 4 levels of administrative division. For that reason, this external class is added to the Greek country profile.

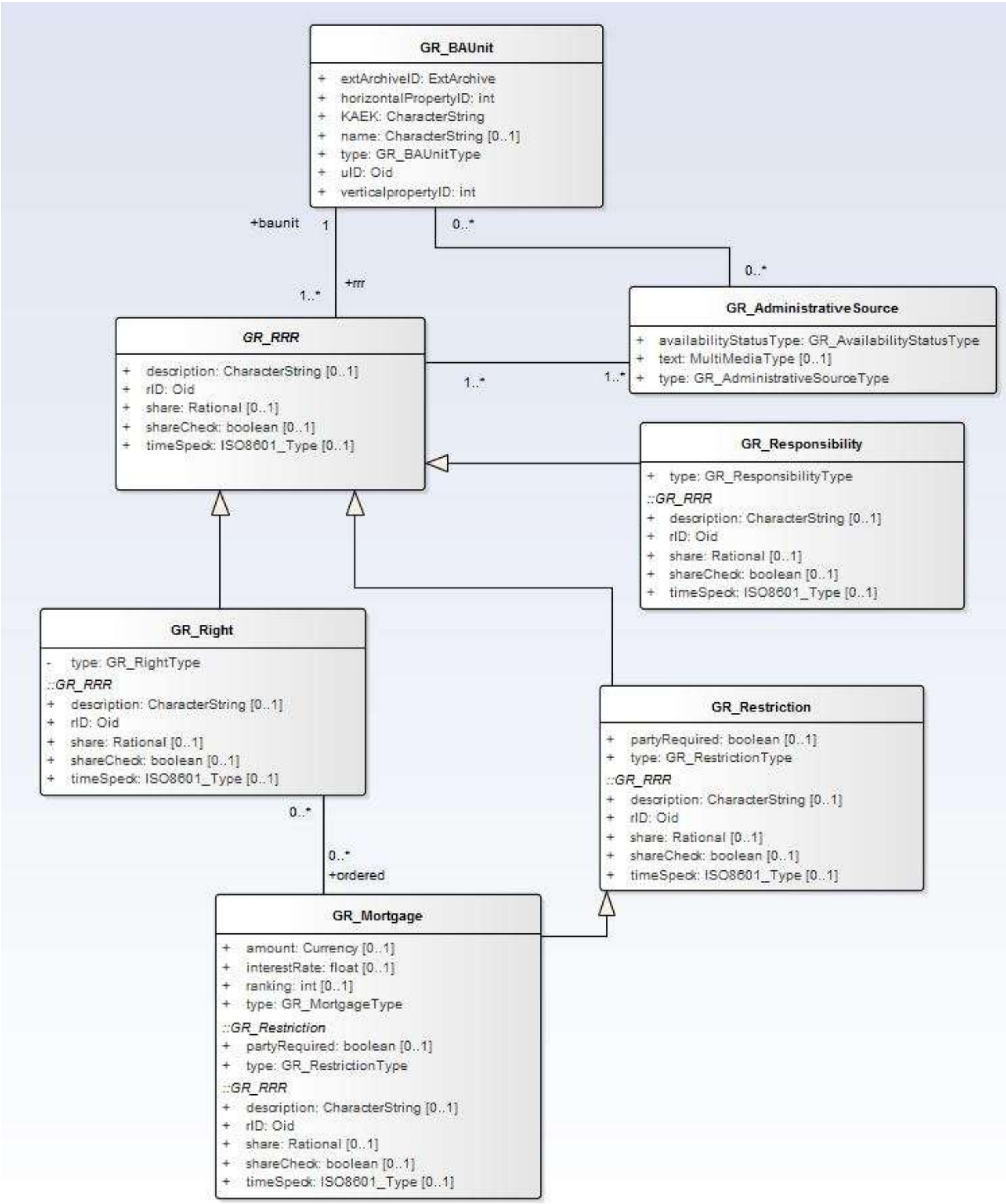


◊ Code list GR_AdministrativeDivisionType

The different levels of administrative division are included in the code list of the attribute GR_AdministrativeDivisionType. In addition, the attribute can take the values: European and International, depending on the transaction that is registered in the system.

◊ Code lists of the Party package

6.4.2. Administrative Package



I. GR_BAUnit

A basic administrative unit is an administrative entity consisting of zero or more spatial units [parcels] against which one or more unique and homogeneous rights, responsibilities or restrictions are associated to the whole entity as included in the Land Administration System. A BAUnit may play the role of a 'party' because it may hold a right of easement over another, usually neighboring and spatial unit.

GR_BAUnit class determines all property rights and corresponds to a part of the class PROP of the HC. Apart from the basic attributes defined by LADM, for the unique identification of each cadastral parcel the Hellenic Cadastre Code Number [KAEK] is used. KAEK is a unique 12 or 16 digit number, the national cadastre code number, used for accessing and querying the cadastral database. A new attribute named KAEK is added at the class LA_BAUnit with the restriction at the data type that the length of the integer should be smaller or equal to 16 digits. The KAEK can be a 16-digit number in case that a horizontal property [apartment, office or shop] exists.

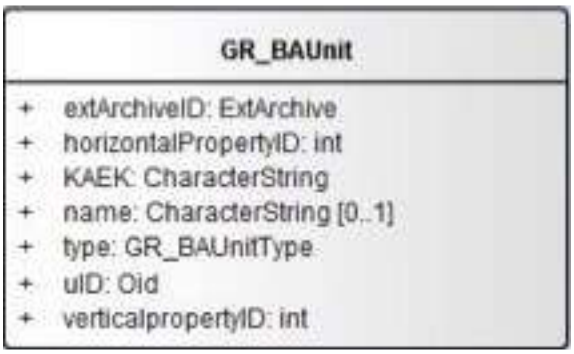
Each of the KAEK 12 digits indicates administrative information concerning the parcel's location, namely:

- The first 2 digits correspond to the Prefecture where the land parcel is located,
- The next 3 digits correspond to the sector of each Municipality, Municipal District or Community,
- The next 2 digits correspond to the cadastral sector of each municipality,
- The next 2 digits correspond to the cadastral section and
- The last 3 digits correspond to the serial number of the land parcel within the section.

In case of a horizontal property four extra digits are added:

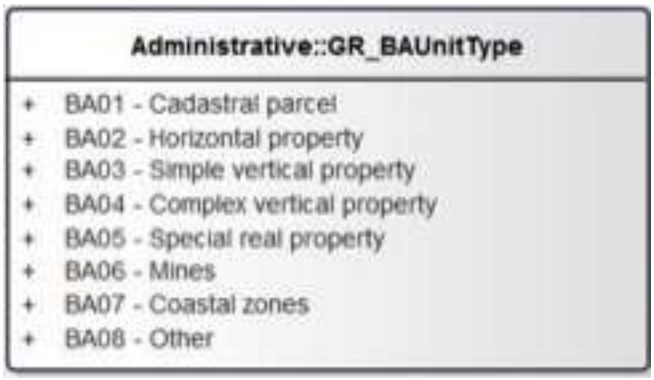
- The next two correspond to the serial number of the building block or flats,
- The last two digits to the floor and the place of the particular horizontal property.

Additionally, two new attributes are added to the GR_BAunit class namely verticalPropertyID [for the identification of vertical ownerships] and horizontalPropertyID [for the identification of horizontal ownerships].



In case that the cadastral survey is finished the unique identifier of the BAUnit is the KAEK. On the other hand, in case that the cadastral survey is still in progress the property code number is used instead. As the GR_BAUnit is a sub-class of the class VersionedObject, all the history of the data is registered. Due to this fact, there is no need to create an extra attribute for the permanent property code number till the end of the cadastral survey. The attribute KAEK is filled with the property code number and when needed it is updated with the KAEK of the BAUnit.

◊ Code list GR_BAUntType

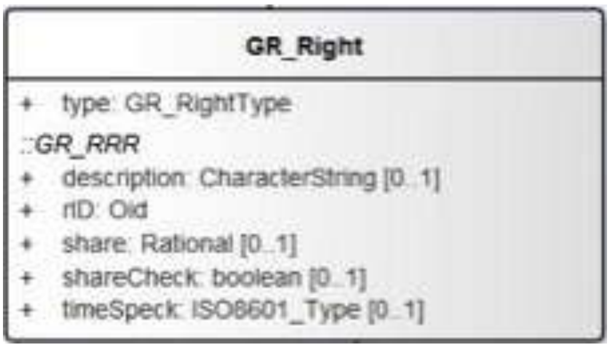


II. GR_RRR

The abstract class GR_RRR defines the rights, restrictions and responsibilities that are registable in the system. It corresponds to the class RIGHT of the HC. Restrictions are not registered separately at the HC; they are included at the table RIGHT. Additionally, the responsibilities are not registered at all in the HC; but it is considered as an important component of the proposed model. It has three classes as specifications: GR_Right, GR_Restriction and GR_Responsibility.

GR_Right

The GR_Right class contains all the rights that can be registered in the Hellenic land administration system. A "right" is an action, activity or class of actions that a system participant may perform on or using an associated resource. A "restriction" is a formal or informal entitlement to refrain from doing something. A "responsibility" is a formal or informal obligation to do something; e.g. the responsibility to clean a ditch or to maintain a monument [Lemmen et al., 2013]. Rights in rem are rights that grant immediate and against all power on the same object [Greek Civil Code 973, Real Property Law and Procedure in the EU, Report Greece].

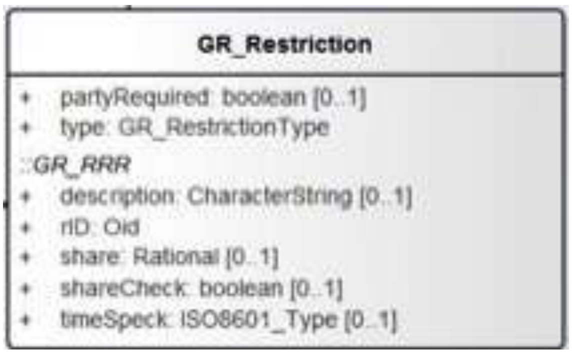


◊ <u>Code list GR_Right_Type</u>

 Gr_Restriction

The restrictions refer to the constraints in the use of the property, for example properties with architectural buildings should have specific land uses. There are also restrictions in the economic activities exercised on properties inside the protection zones of archaeological spaces or mines [Dimopoulou and Gogolou, 2013].

◊ <u>Code list GR_RestrictionType</u>



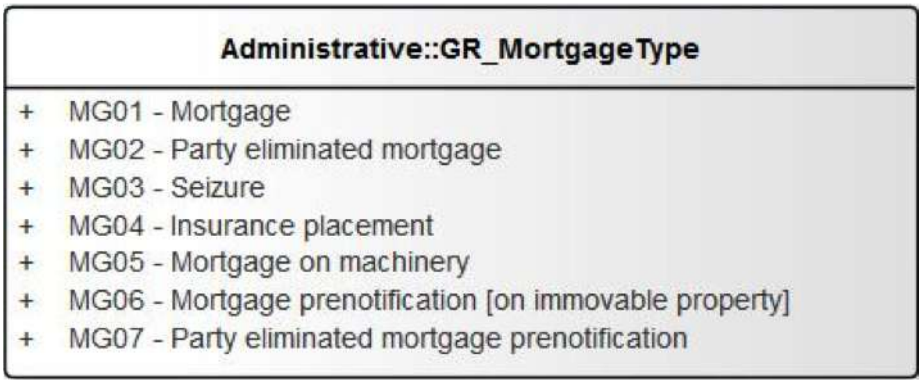
GR_Mortgage

A mortgage is a special restriction of the ownership right. In fact it is a security right to provide a maximum guarantee that [bank] loans for purchase of real estate are repaid. Mortgage is a right in rem and a subsequent right to secure a future claim or a claim in provision of the borrower with a preferential satisfaction of him/her regarding the real estate by the owner of the real estate; who may be a debtor or even a third party; who consented on a mortgage to be recorded on his real estate [Real Property Law and Procedure in the EU, Report Greece].

At the HC model the values of this attribute belong to the RIGHT table.

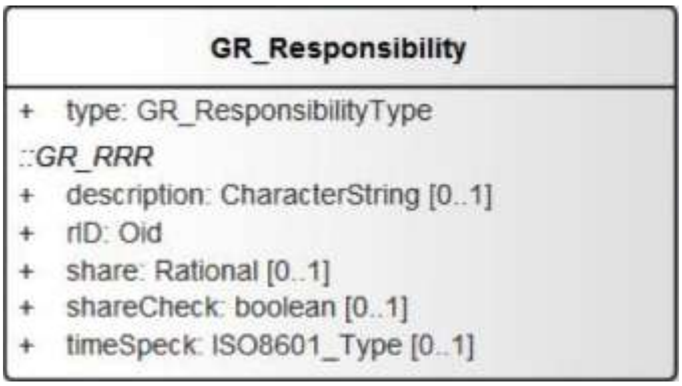
◊ Code list GR_MortgageType

According to the HC the different types of mortgage that can be registered in the system are the following:



GR_Responsibility

The responsibilities are related to the obligations the owners have for the protection of the spatial units and are extracted from the corresponding legislation. For instance, the State is obliged to protect, promote and make the antiquities accessible, a fact that generates responsibilities for the owners of properties with archaeological interest. Until now, at the data model of the HC the responsibilities where not registered. However it is considered very important to register responsibilities derived from the customary law, or everyday life, such as monuments and/or traditional buildings inspection.

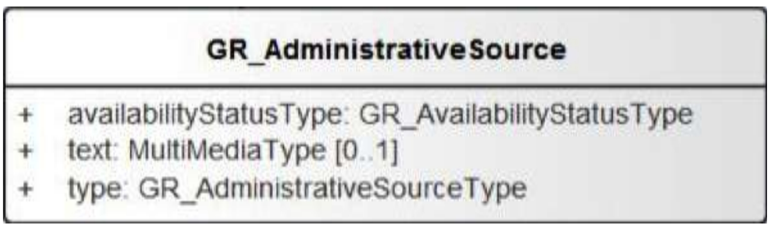


◊ Code list GR_ResponsibilityType

III. GR_AdministrativeSource

One of the important foundations of LADM is the fact that all information in the system should originate from source documents and that the association to the source document is explicitly included [Lemmen, 2012]. The class GR_AdministrativeSource is the source with the administrative description of the parties involved; the rights, restrictions and responsibilities created as well as the basic administrative units affected. In case of administrative source documents [usually titles] there are associations with right, restriction, [including mortgage] and responsibility [RRR] and basic administrative unit [BAUnit].

GR_AdministrativeSource associates with GR_RRR and GR_BAUnit and corresponds to classes DOC and DOC_BEN_RIGHT of the HC. For the proposed model it is considered that the availability status of each source it is important and is added as an extra attribute to the class GR_AdministrativeSource.



◊ Code list GR_AdministrativeSourceType

Administrative::LA_AdministrativeSourceType

+ AS01 - Presidential decree
+ AS02 - Legislative decree
+ AS03 - Royal decree
+ AS04 - Notarial deed
+ AS05 - Court decision
+ AS06 - Law
+ AS07 - Imperative law
+ AS08 - Revocable administrative act
+ AS09 - Administrative act
+ AS10 - Official state deed
+ AS11 - Notary deed
+ AS12 - Documentation deed
+ AS13 - Usucaption documentation
+ AS14 - Mortgage
+ AS15 - Permit
+ AS16 - Building permit
+ AS17 - Geotechnical impact
+ AS18 - Environmental impact assessment
+ AS19 - Lease contract
+ AS20 - Public work contract
+ AS21 - Document of plea
+ AS22 - Stategic plan
+ AS23 - General urban plan
+ AS24 - Urban control zone
+ AS25 - City plan
+ AS26 - Historical source

◊ Code list GR_AvailabilityStatusType

**Administrative::
GR_AvailabilityStatusType**

+ AV01 - Registered source
+ AV02 - No Registered source
+ AV03 - Incomplete registration
+ AV04 - Destroyed registration
+ AV05 - Undefined

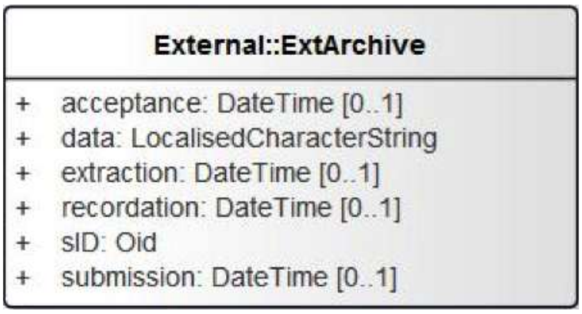
IV. Administrative Package external classes

Two external classes have been created for the administrative package; for the ways of ownership [extWayofOwnership] and an archive. To make the current system compliant to LADM, the spatial source, deed or title, would be identified by a unique number. For that reason the External archive class is introduce; since there are different organizations that maintain the sources in which the transactions are based which will be linked via the ExternalArchiveID. The code list for the different types of ways of ownership are according to the existing code list that HC data model uses.

External Way of ownership

◊ Code list GR_Wayof OwnershipType

External Archive

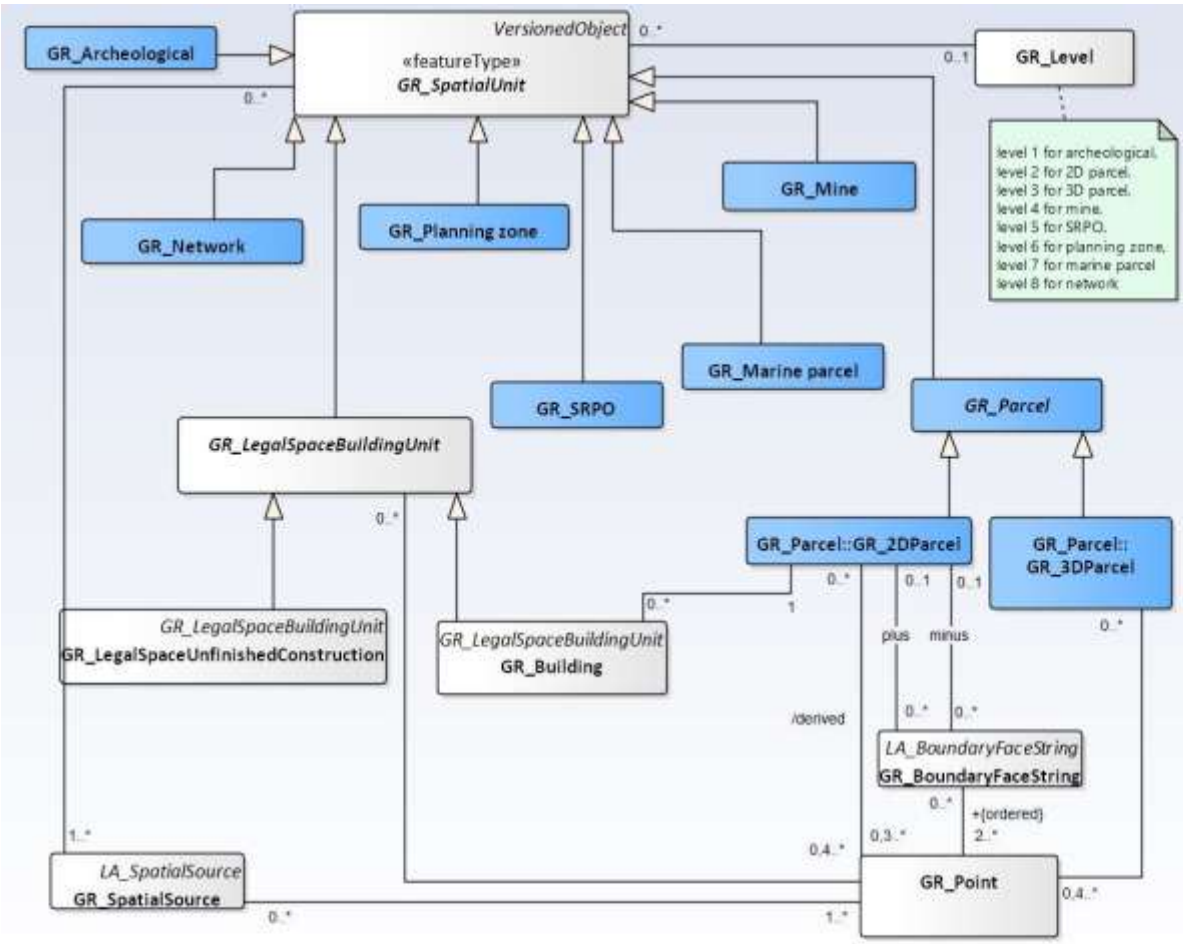


The list of all the code lists of the non-spatial part of the proposed model is included in Appendix C.

6.4.3. SpatialPackage

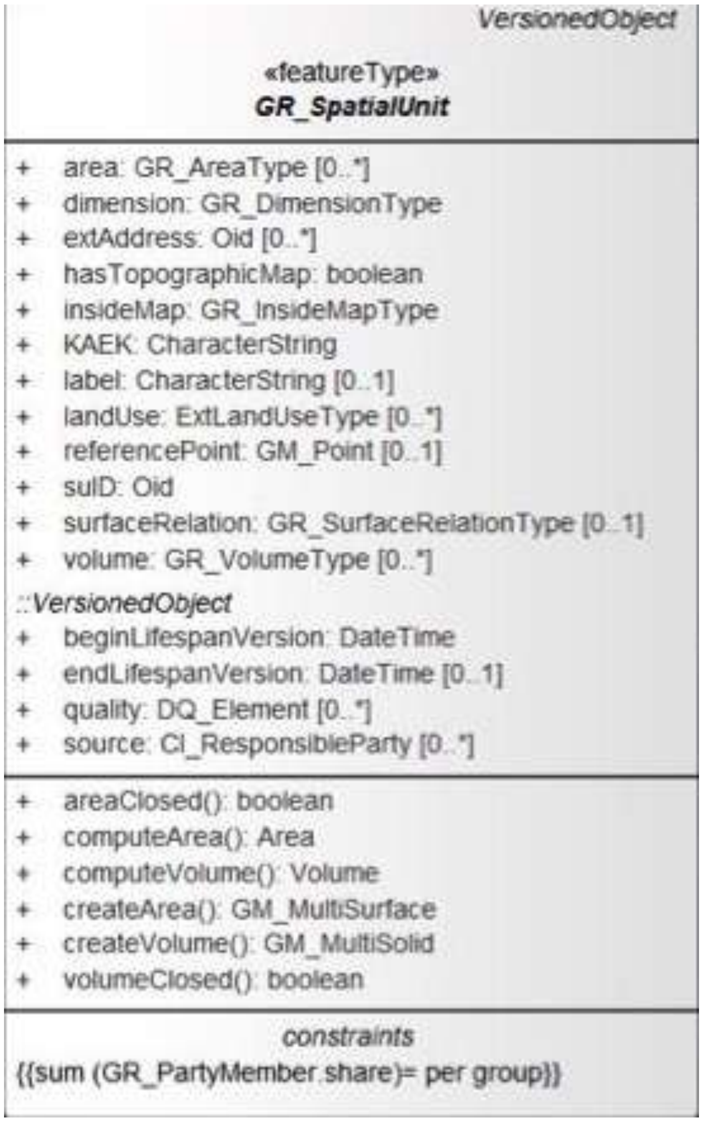
In Greece there is a wide range of different spatial units. In order to make the model comprehensive and future proof, all those spatial units can be supported including 2D and 3D properties, marine parcels, mines, parcels with archeological interest, special property right objects, utility networks and the planning zones. Even if all those different spatial units are not supported today by the NCMA S.A. or another institution or organization; e.g. the marine parcel; the model is designed to cover all the possible cases also for the future. For the best organization and management, the various types of spatial units are organized in levels.

At the next figure an overview of the spatial part of the model is presented.



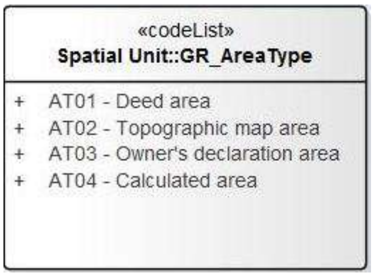
I. GR_SpatialUnit

GR_SpatialUnit is the main class of the Spatial Package. It consists of a single area [or multiple area] of land and/ or water, or a single volume [or multiple volumes] of space [Lemmen, 2012] and corresponds to part of the PROP class of the HC. Spatial units are structured in a way to support the creation and management of the basic administrative units.

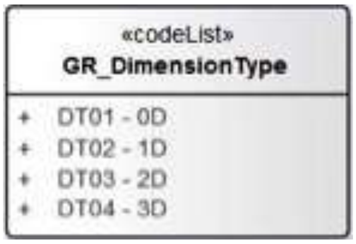


◊ Code list GR_AreaType

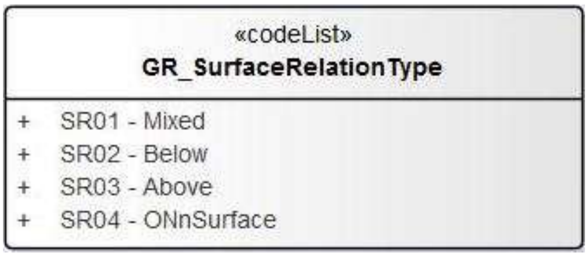
In the HC there are many areas registered due to the various information that have been gathered. In particular, the area from the deed; the area from the topographic map; the area from the GIS registered during the cadastral survey and the area mentioned on the owner's declaration.



◊ Code list GR_DimensionType



◊ Code list GR_SurfaceRelationType

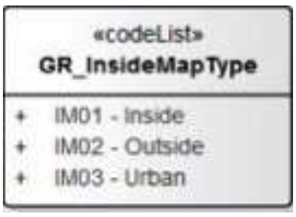


◊ Code list hasTopoMapType

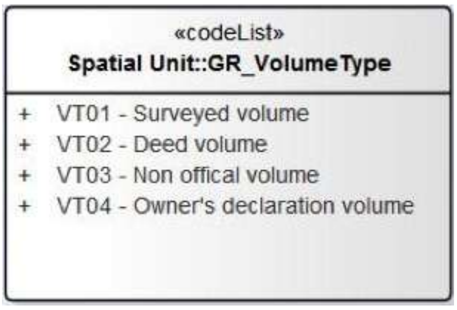
The attribute hasTopoMap is added to the GR_SpatialUnit class, as it is also a class on the HC data model, showing whether together with the ownership declaration a topographic map was attached or not. It is a Boolean expression.

◊ Code list GR_InsideMapType

The attribute InsideMap is added to the GR_SpatialUnit class, as it is also a class on the HC data model. It signifies if the property is inside the city plan or not. According to that, the legislative framework, the RRRs and also the value of the property change.



◊ Code list GR_VolumeValue

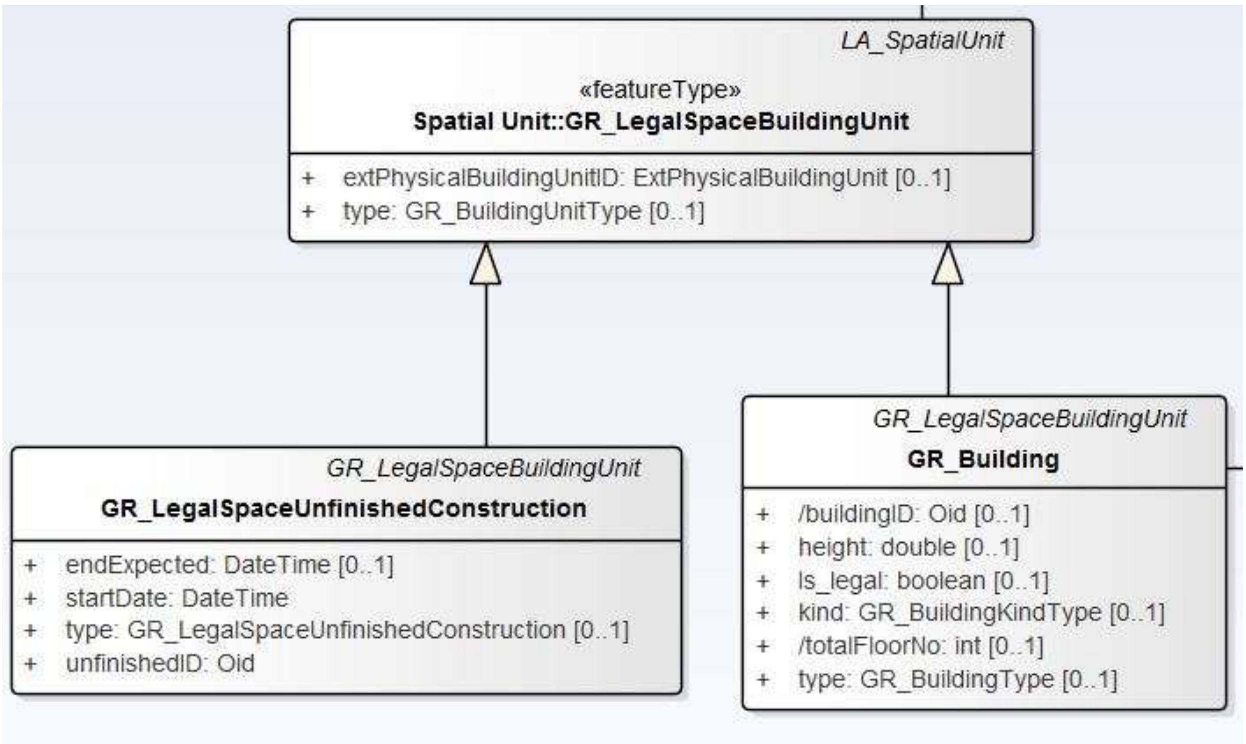


II. GRSpatialUnitGroup

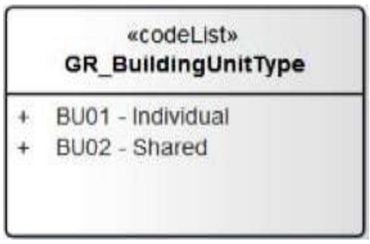
The class consists of any number of spatial units considered as an entity; e.g. a municipality and is realized by an aggregation relationship of GR_SpatialUnitGroup onto itself. A spatial unit group may be a grouping of other spatial unit groups. According to Lemmen, 2012, in implementation of LADM this is to enable the inclusion of spatial unit identifiers in hierarchical zones.

III. GR_LegalSpaceBuildingUnit

It contains the legal space, which does not necessarily coincide with the physical space of the building unit. LADM provides the opportunity to link the legal space with the class ExtPhysicalBuildingUnit for the external registration of mapping data of building units.



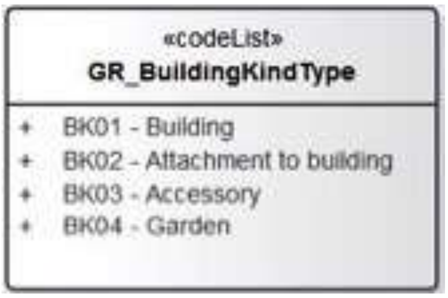
◊ <u>Code list for BuildingUnitType</u>



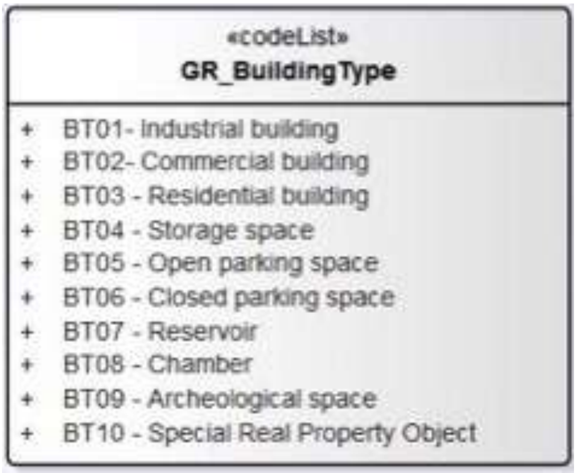
IV. GR_LegalSpaceBuilding

The building unit concerns legal space, which does not necessarily coincide with the physical space of a building. As in Greece there are many constructions that are not yet finished, or there have been for many years unfinished and they still remain like that a sub-class of GR_LegalSpaceBuilding has created in order to register the unfinished constructions. In case that the unfinished construction is a building, when it is completed, the endExpected attribute of the class GR_LegalSpaceUnfinishedConstructions will have the same value with the creatrionDate of GR_Building class.

◊ <u>Code list of BuildingKindType</u>

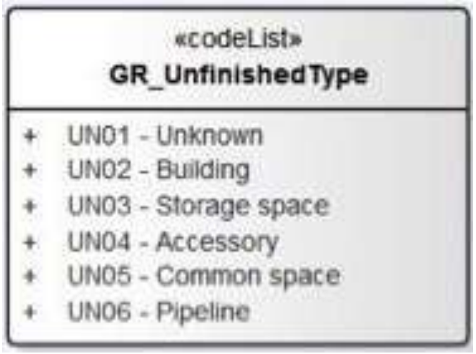


◊ <u>Code list GR_BuildingType</u>



V. GR_LegalSpaceUnfinished

◊ **Code list GR_UnfinishedType**

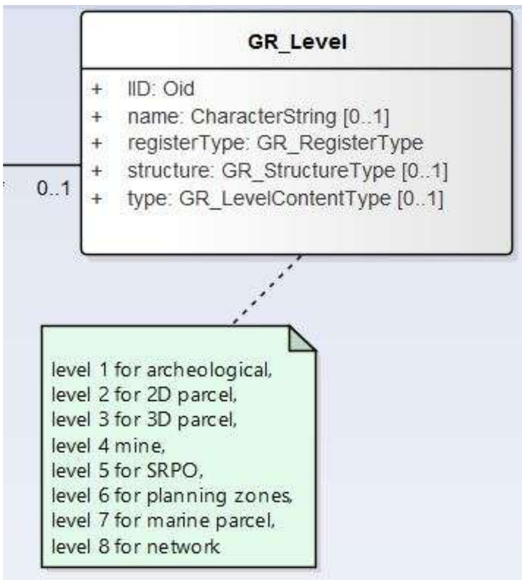


VI. GR_Level

According to ISO 19152, 2012, LA_Level and therefore, GR_Level is a collection of spatial units with a geometric or thematic coherence. This concept is important for organizing the spatial units in LADM. In this way, in relation to the principle of "*legal independence*" [Kaufmann and Steudler 1998] different groups of coherent spatial units can be created. This allows for the flexible introduction of spatial data from different sources and accuracies, including utility networks, buildings and other 3D spatial units, such as mining claims, or construction works, etc.

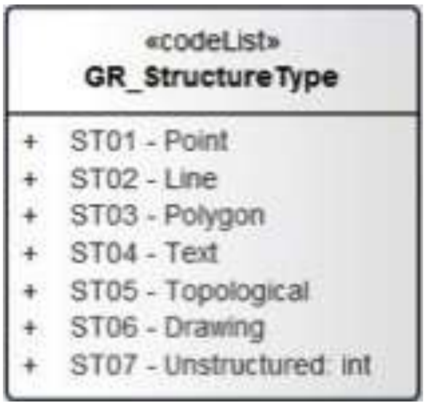
To make the proposed model comprehensive and future proof, a wide range of spatial units can be supported including spaces with archeological interest [2D or 3D], mines, and special real property objects. The various types of spatial units are organized in levels using the class GR_Level. For this class there is an attribute type that described level type of the spatial unit, which will include: archeological space, land parcels, marine parcels, panning zones, mines and SRPOs. The code list for these attributes can refer to GR_LevelContentType.

For Greece, the following levels are proposed: level 1 for archeological, level 2 for 2D parcel, level 3 for 3D parcel, level 4 for mines, level 5 for SPROs, level 6 for planning zones and level 7 for marine parcel. In the involved classes a constraint has been added to make this more explicit. For instance, GR_Mine has a constraint GR_Level.name 'level 4".

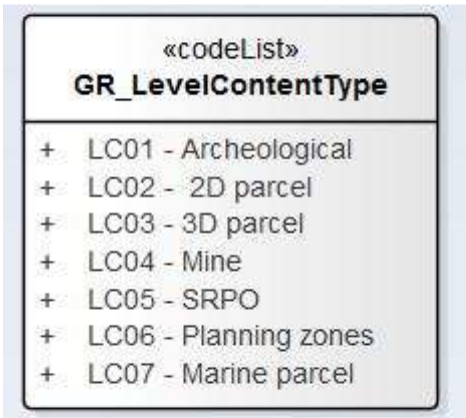


◊ GR_RegisterType

◊ Code list of GR_StructureType



◊ Code list of GR_LevelContentType



LC01 – Archeological

The Greek civilization is important and affected the evolution of European cultures, contributing to modern western civilizations. Political ideas, such as democracy, philosophy, sciences, architecture and cultural heritage, are all representatives of the rich Greek civilization. In modern times the remaining Greek cultural heritage is considered to be world heritage, due to the importance and the oldness of the antiquities, gathering the global interest of people, who travel in Greece to visit them.

Until nowadays, many types of legislation have been issued in order to contribute to the conservation of the cultural heritage in Greece, all tucked under the title "Archaeological Legislature".

The Greek State has encompassed all the international conventions, declarations, agreements and European directives concerning the protection of all aspects of cultural heritage in the legislation, e.g. Convention for the Protection of World Natural and Cultural Heritage. However, the adoption of laws confronts many problems, such as the inadequacy of protecting the public space, which leads to infringement by the individuals, the bad conservation of the antiquities and most important, the lack of efficient management structures to the protection services.

As the archaeological space in Greece is vital for the conservation of the antiquities it reflects the necessity for the implementation of a special class. In this class the type of the archeological area that is registered is important as well as the protection zone. This depends if the archeological sites are inside or outside of settlements.

I. Archaeological sites outside of settlements

Archaeological site beyond settlements (i.e. no existing city plans or legally existing settlements) are protected by two kinds of protection zones: Protection zone A and Protection zone B.

Protection Zone A

Building activities are totally prohibited. The only exception is: construction of edifices or additions to existing buildings may be allowed, where necessary for the enhancement of the monuments' sites as well as for facilitating their use. A ministerial decision sets the building terms for these types of constructions.

Protection Zone B

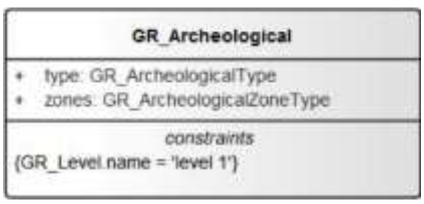
Agriculture, stock-breeding, hunting or other related activities can only be carried out upon special permit.

II. Archaeological sites within settlements

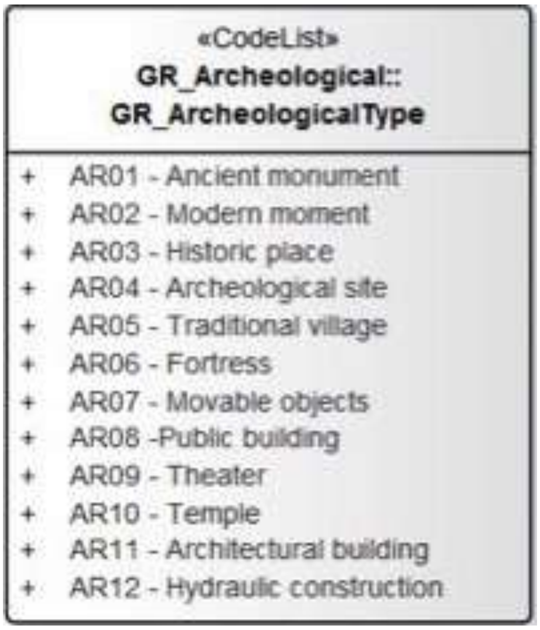
As a general rule any intervention impairing the character of the urban web of the buildings or disrupting the relationship between the buildings and open spaces is prohibited. The protection zones applicable for archaeological sites outside of settlements can be also applied to archaeological sites within settlements. In non-active settlements it is prohibited to erect new buildings.

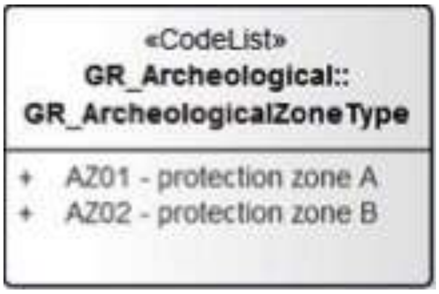
Only upon permit granted by decision of the Minister of Culture and subject to restrictions stipulated by law are the use, construction (only if they are compatible with the character of the settlement), restoration and demolition of existing edifices allowed. Within archaeological sites which are active settlements, special rules apply with respect to restrictions to ownership, land use or use of buildings. These rules are being set by ministerial decision in each case.

In order to best manage all those special cases, a new level named Archeological is created at the proposed model, as shown in the next figure:



And the code lists of its attributes are the following:

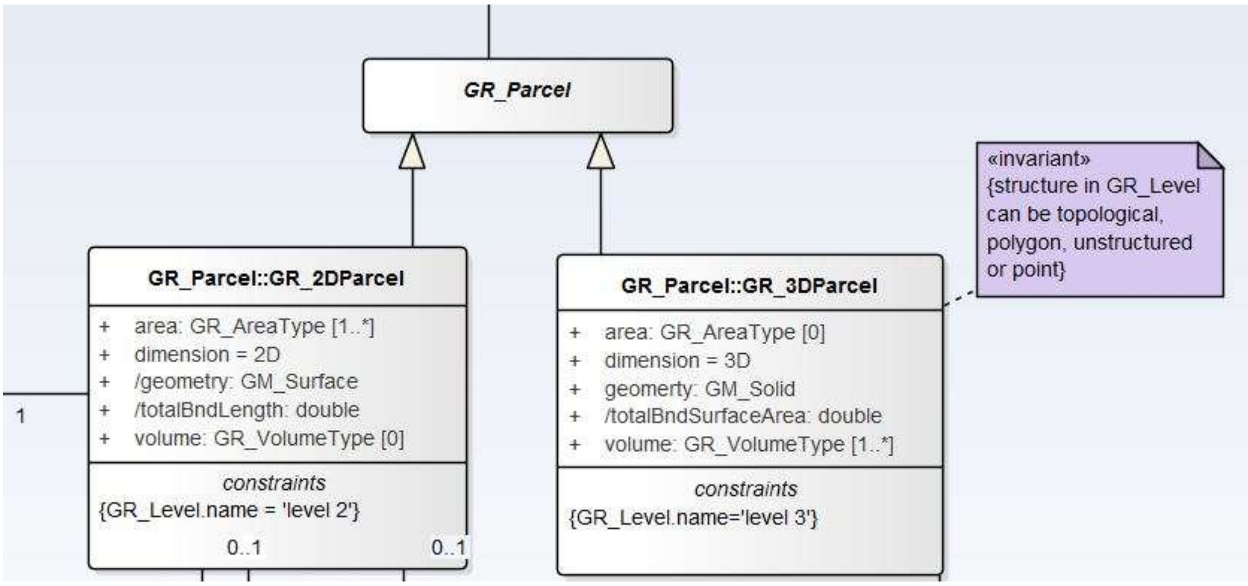




LC02 – 2D property & LC03 – 3D property

In the Greek country profile, there are some attributes, which are repeated after inhering them from LA_ class. The reason for this is that they have different multiplicity the same attribute has in the corresponding LA_ class. For instance, LA_AreaValue in GR_3DParcel class has 0 multiplicity because this class has no value for area and in GR_2DParcel the multiplicity of this attribute is [1..*]: Indicating the presence of one or more area values. The original LA_ class (LA_SpatialUnit) for the area attribute has multiplicity zero and more [0..*]. Note that some example area types of LA_AreaValue are: deed area, owner's declaration area, calculated area, and topographic map area.

In the proposed country profile, spatial units can be 2D or 3D. Nowadays, the parcels registered in the HC are 2D, but there are many cases that need 3D description as mentioned in 5.7. The model has introduced an abstract class GR_Parcel holding the attributes of a parcel and this class has two specializations GR_2DParcel and GR_3DParcel, with their own attributes and structure. Currently GR_2DParcel is based on 2D topology with references to shared boundaries (GR_BoundaryFaceString).



LC04 – Mines

Greece is one of the EU countries that posses substantial mineral wealth consisting of a variety of minerals and ores with a large industrial and economic interest. Nowadays, the mining and mineral industry faces some of the most difficult sustainability challenges of any industrial sector. Some scholars claim that mining is an inherently unsustainable activity, since is based on the extraction of non-renewable resources. However, the last years various initiatives were launched with a view to secure reliable and undistorted access to raw materials for Europe and also in an international level.

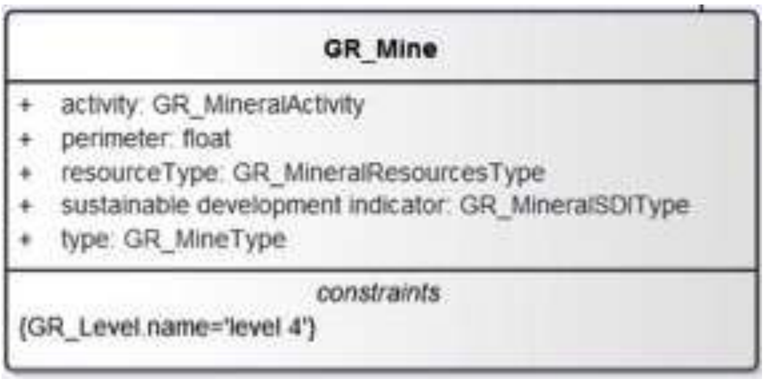
The mining and mineral industry started to develop a framework for sustainability indicators [SDIs] as a tool for performance assessment and to demonstrate continuous improvements as proposed by the Mining, Minerals and Sustainable Development project [MMSD, 2002 a&b] and later by other [GMEA 2006; Valta et al. 2007].

Tzeferis et al., [2012] examine the most important SD indicators for Greece using company-supplied information including employment matters, environmental management, waste management, energy and water management, local development, etc. The results, which have not been fully verified yet, were compiled primarily from the annual sustainability reports of GMEA companies.

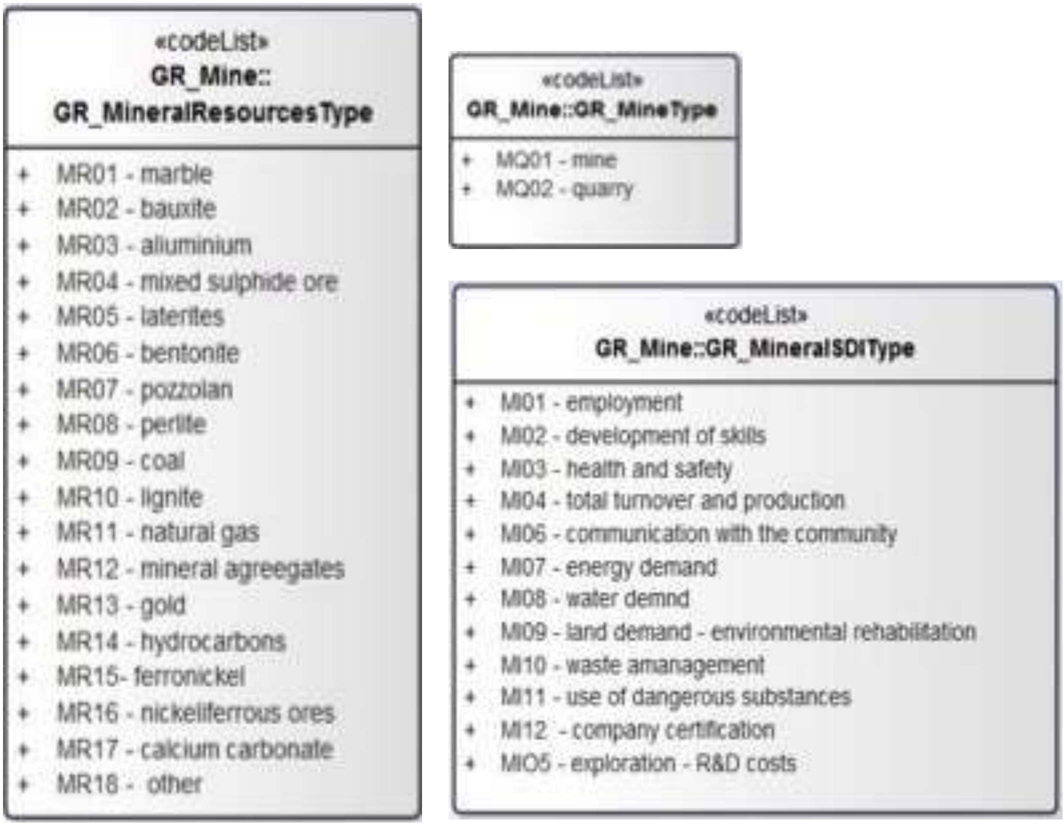
The Greek Mining/Metallurgical Industry [GMMI] constitutes an important sector of the economic activity of the country as it supplies essential raw materials for primary industries and various downstream users.

The most common and known production data of various mineral commodities produced in Greece are the following: bauxite, aluminium, mixed sulphide ore, nickeliferrous ores, ferronickel, bentonite, pozzolan, perlite, calcium carbonate, lignite, mineral aggregates, marble, etc.. Reported data combine data from statistics provided by the Mineral Resources Division of the Ministry of Environment, Energy and Climate Change and the annual statistics provided by GMEA.

The perspectives of the Greek mineral industry appear to be positive, relying mainly to its export orientation. However, the industry has to identify and exploit the trends and opportunities of the international business environment in order to overcome crisis, remain competitive and further improve its position and perspectives. Mineral sources are of outmost important for Greece and special legislation framework applies to them. Additionally, the nature of the parcels where mines and quarries are found is unique due to the geomorphological characteristics. For those reasons and for the best exploitation of the natural resources it is considered that a separate level for mines should be created at the proposed model. The attributes of this class are the different mineral resources types, the sustainable development indicators and the mineral activity that takes place in the mine, as shown in the next figures.



And the code lists of its attributes are the following:



LC05 – SRPO

SRPOs considered an individual entity also in the existing model of the HC. This is due to the fact that they are properties built above or below other properties, usually found on the Greek islands. Customary law applies to mostly in the Aegean islands creating complex RRRs, mixed up in multiple layers below or above the surface. Legal relations on those RRRs are presented through characteristic cases and examples of complex 3D reality. The integration of these legally defined spaces to a 3D cadastral system should leave no doubt about the way.

As SRPOs are already a separate entity it is considered that a new level for them should be created. Their characteristics, the legislation framework, their role in the history and tradition

RRRs are connected and affect each other, as well as connect parties and property units. Separate ground floor (eg. katoi) and upper floor (eg. anoi) residences have been traditionally under a system of horizontal property, evidently not complying with the Roman accession rule. The owner of the ground floor also owned the land parcel, while the owner of the upper floor owned the roof (and air), having no land share. Under this special system of co-ownership, each floor's rights, even without land share, are separate, transferable and registrable. It is clear that there is no way to explicitly describe those relationships in two dimensions. For that reason, it is mandatory for this level to use the third dimension for registration and representation.

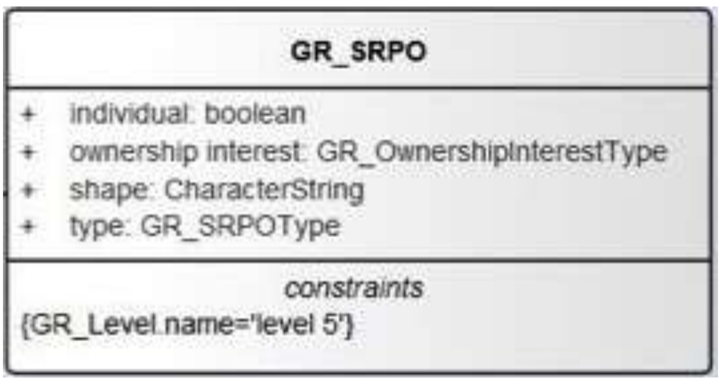
The SRPOs can be divided into two categories: individual and non-individual properties. The non-individual properties are registered in the HC together with a parcel. Therefore, the individual properties can be described depending on their percentage on the ownership interest.

According to their percentage, three groups are formed:

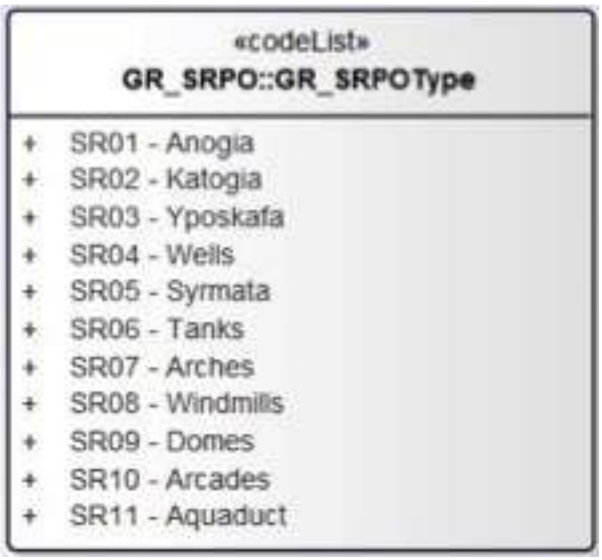
- properties which have 1000 ‰ ownership interest,
- properties that have less than 1000 ‰and
- properties that don't have ownership interest at all.

Those categories are depicted in the class of SRPOs as separate attributes as shown in the figure below.

Additionally, for the SRPOs an ontology have been created using the Protégé software and is further explained in 6.4.4.



And the code lists of its attributes are the following:



LC06 – Planning zones

According to the Greek Constitution (voted in 1975 and revised in 1986 and 2001), spatial planning (that is both urban and national and regional spatial planning) is placed under the regulatory authority and the control of the State, in the aim of serving the functionality and the development of settlements and of securing the best possible living conditions.

At the national level, the main institution responsible for urban and regional planning is the Ministry for the Environment, Energy and Climate Change [YPEKA]. It is responsible for the elaboration, approval and implementation of urban master plans; statutory town plans, housing plans and environmental protection programs. It is also responsible for the elaboration, monitoring, evaluation and revision of national and regional strategic spatial plans. Other ministries, responsible for sectors as industry, tourism, agriculture, transport and energy, intervene also in the formulation and implementation of spatial planning policy especially in the field of sectoral spatial plans.

The 13 Regions in which the country is actually divided are entrusted with several planning responsibilities concerned mainly with the elaboration, the approval, the amendment, the revision and the monitoring and control of different types of urban plans, the approval of zones for the transfer of floor-area ratio and the approval of departures from general building rules in the case of non-residential buildings (buildings used for health care, education and welfare services, as well as industrial plants and public sports facilities).

Apart from regional administrations, a great number of second-tier (Prefectural self-government) and first-tier (Municipalities and Communes) local authorities intervene in the planning process. In the production and approval of statutory plans the role of local authorities is mostly advisory, while the hard core of their responsibilities is concerned with the delivery of building permits and other licenses and the implementation of town plans.

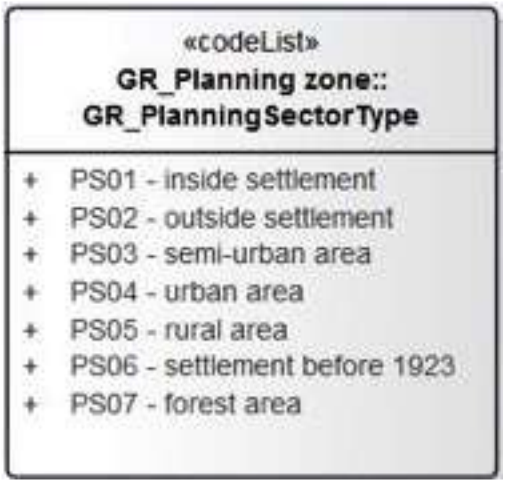
Greek planning law comprises a wide range of instruments which extent from strategic and framework plans at the national and regional levels to regulatory town plans and zones at the local level. Existing legislation establishes a hierarchical structure between different types of plans as presented into the next table. The organization of the levels of planning largely reflects the spatial scale at which plans operate (national, regional, local), without, however, having a strict correspondence with the existing levels of government [Commission of the European Communities, 2000].

Moreover, planning control in Greece is realized through the building permit. This permit is required for any work of construction in or out of a settlement. It is a combined system of planning and building control, which regulates building construction and demolition, as well as land-use change.

Besides building permit, other consents depending on the use of the building or its location are needed. Among them, we should mention the consent required if development is to take place on or around monuments and historic buildings (article 10 of L. 3028/2002) and the approval of environmental conditions required in the case of public or private projects that may have significant impact on the environment (articles 3-5 of L. 1650/1986 as amended by L. 3010/2002). Both permits are prerequisites for the granting of the building permit.

Concluding, the planning zones are very important for each country and in particular for Greece as they define the activities, policies, land uses and the restrictions for the entire territory of the country. For all the above mentioned they are considered as a separate level in the proposed model. The attributes are the type of the plans, the building regulations, the planning sectors that are created from the corresponding plans and the planning level, as presented in the next figure:

And the code lists of its attributes are the following:


«codeList»
GR_Planning zone::
GR_PlanningSectorType
+ PS01 - inside settlement
+ PS02 - outside settlement
+ PS03 - semi-urban area
+ PS04 - urban area
+ PS05 - rural area
+ PS06 - settlement before 1923
+ PS07 - forest area

Types of Plans	Area covered	Responsible authority for the approval
Strategic: General Framework for Spatial Planning and Sustainable Development	The whole country	National Parliament
Special Frameworks for Spatial Planning and Sustainable Development	Special areas of the country (e.g. coastal areas and islands, mountainous and lagging zones), sectors of activities (e.g. industry) of national importance or networks and technical social and administrative services of national interest	Co-ordinating Committee of Governmental Policy for Spatial Planning and Sustainable Development (inter-governmental organ)
Regional Frameworks for Spatial Planning and Sustainable Development	The area of a Region	Minister for the Environment, Spatial Planning and Public Works
Framework: Master Plans for Athens and Thessaloniki	The Greater Area of Athens and Thessaloniki	Approved by Parliament Act (L.1515/85 and 1561/1985)
Master Plans for other major cities	The Greater Area of the selected cities	President of the Republic (Presidential Decree)
General Urban Plans (GPSs) and Plans of Spatial and Settlement Organization for Open Cities (SHOOAPs)	The whole of one municipality of more than 2.000 habitants or the whole of one or more municipalities and communes of rural areas with a population of less of 2.000 habitants each	General Secretary of the Region
Regulatory: Different types of town-plans (Poleodomiki Meleti,, City plan)	Neighborhood level of one Municipality or Commune	Presidential Decree (with the exception of “minor modifications” of the above plans that may be approved by the relevant local authorities)
Implementation and land contribution plans (Implementation act)	Neighborhood level of one Municipality or Commune	Prefect or Mayor

Zoning instruments	Functional planning urban or/ and rural areas	Minister for the Environment, Spatial Planning and Public Works

LC07 - Marine parcel

The marine environment introduces complexities that are not inherent in land based spatial data. Marine environment is subject to a myriad of legal interests due to international and national institutional frameworks. The marine space involves RRRs that are time based and overlapping in nature. Some of these rights include United Nations Convention on Law of the Sea (UNCLOS) and national maritime zones, sovereign and administrative rights, private commercial rights, mineral resources rights, development rights, riparian rights, and navigation.

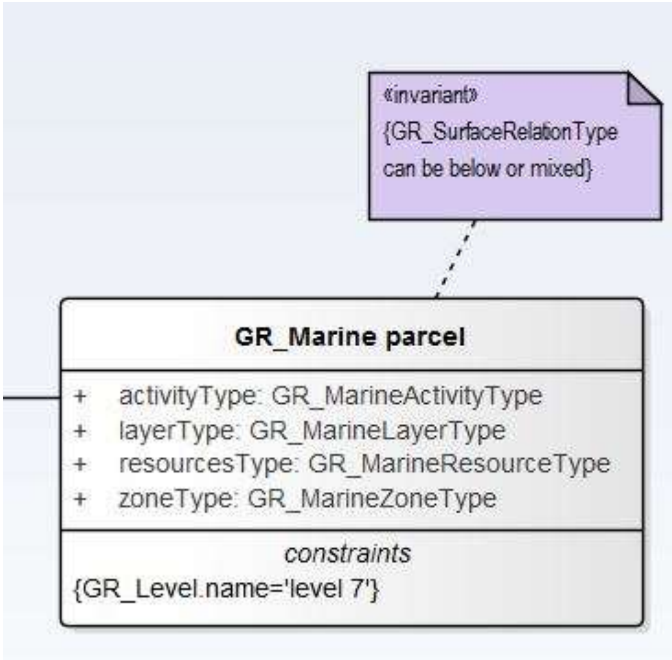
Therefore, in order a marine system to be successful must be subsumed into a national approach to administration of land, coastal, and marine environments, but the identification of the unique marine features and the appropriate management of them is required.

In the existing model of the HC, according to the technical specifications of the NCMA SA, the marine parts in which the cadastral survey is in progress are not assigned with a KAEK and therefore no information about them is recorded. Also, the current LADM version does not elaborate the marine part. Although there are several proposals regarding the subject of marine cadastre that deal with varying issues, however there is a lack of literature that deals with marine cadastre data models and the incorporation of the marine object in the land administration data model.

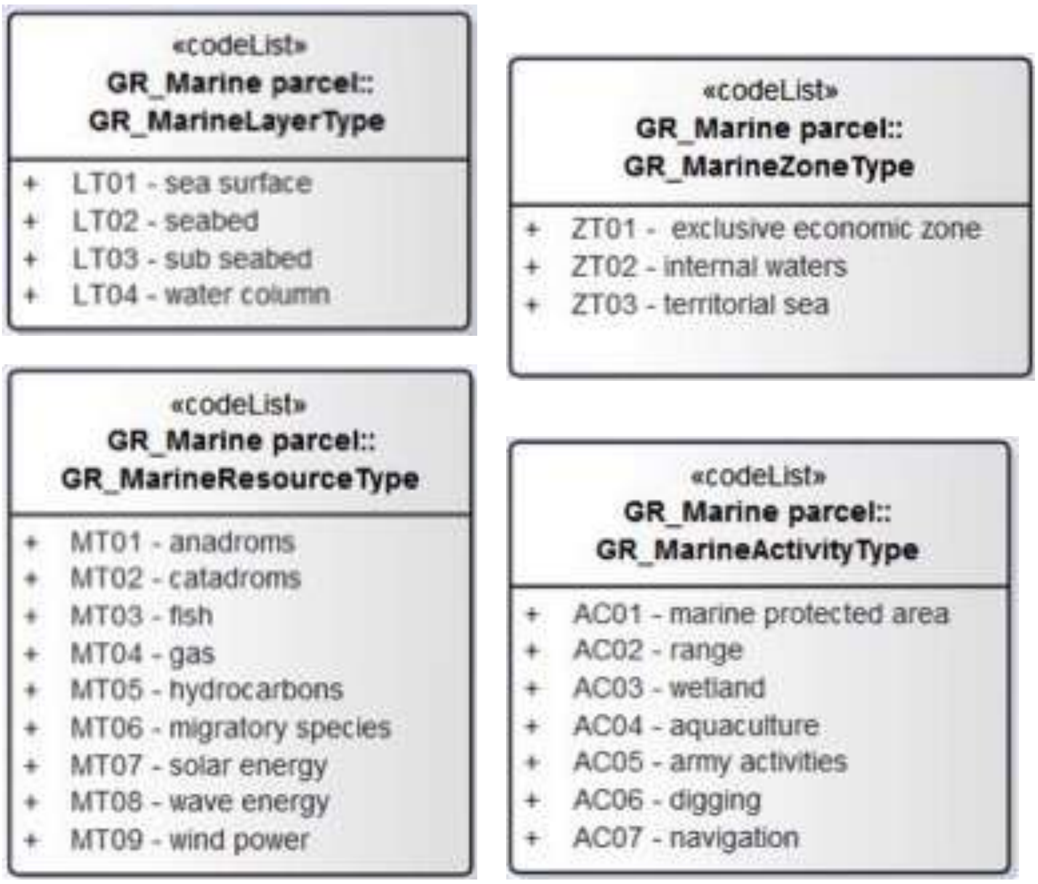
In the proposed model for the registration of the marine interests spatial extent, the GR_Marine class is suggested.

Marine objects can be described as sea surface objects, water volume objects, seabed objects, and sub seabed objects. That is defined in the attribute MarineLayerType. These can be demarcated up to a country's Exclusive Economic Zone (EEZ). The management, exploration and exploitation of marine resources are usually for the benefit of the country and stakeholders up to its EEZ. So in order to define the location of marine spatial unit the attribute MarineZoneType is introduced. The main characteristic of the marine environment is that the administration system is needed mostly for the management of resources. The transaction object is not the space (as in land), but the resources that included in this space. So the registration of natural resources is necessary, when a marine interest is captured [Athanasiou, 2014], that is why the attribute MarineResourxeType is proposed.

In the marine environment the Party is less likely to be an individual and would most likely be a group, such as a consortium for oil mining. International law (e.g. UNCLOS, or customary international law), public rights, and government ownership more frequently take precedence over any private rights that do exist in the sea [Cockburn et al., 2003]. Regarding the legal space, while spatial units in the land cadastre can have specializations where objects can coincide with the legal space, this is very rarely in the marine cadastre. [Griffith-Charles & Sutherland, 2014].



And the code lists of its attributes are the following:



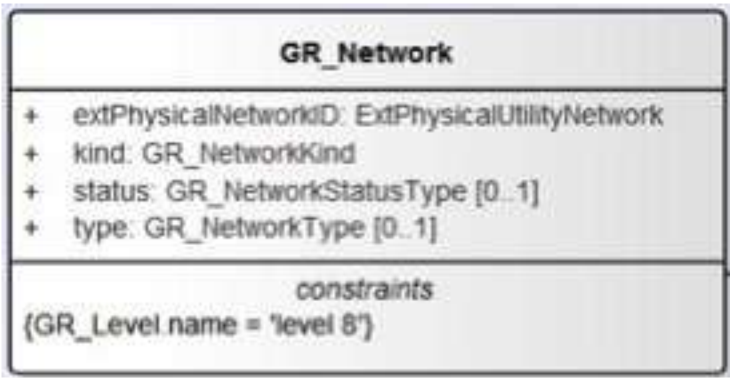
LC08 - Networks

Networks can be divided into transportation and utility networks. It is considered as a group of objects with special characteristics that usually impose restrictions and easements to the properties and should be managed individually.

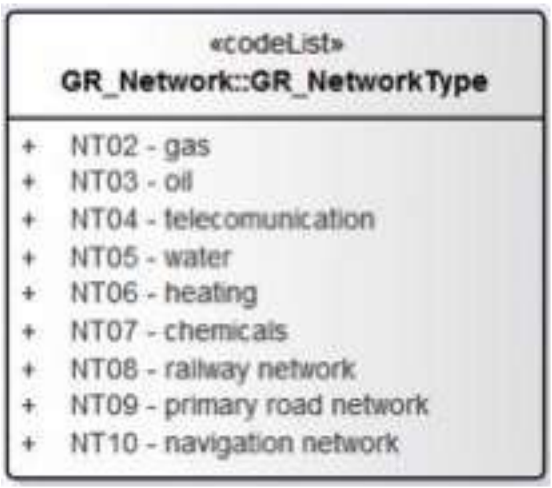
According to the model of the HC, the information that is registered concerns only the utilities networks and refers to the legal status, not to the physical. This means that only the rights, restrictions and responsibilities related to the network are described. LADM provides the opportunity to link the physical with the legal aspect of the utility networks by adding an attribute for connecting with an external database where the spatial components of a utility are described.

Additionally, the type and the status of the networks are registered in the level as presented in the following image:

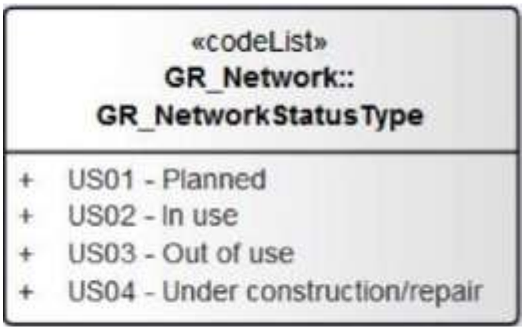
Additionally, in this level the time aspect is very important. For instance, the Trans Adriatic Pipeline [TAP] affects the landowners and land users living along the corridor in the northern Greece and will be compensated fairly for the time that the corridor affects their properties.



◊ <u>Code list GR_UtilityNetworkType</u>



◊ Code list GR_UtilityNetworkStatusType



The list of all the code lists of the spatial part of the proposed model is included in Appendix C.

VII. Spatial package External classes

In the LADM design, any specification is not presented on the association of land use/cover information with LADM classes but for the defined association relations between LA_SpatialUnit class and external land use/cover classes. This is because LADM provides a basic, abstract model focused on land administration and especially on the legal part. Undoubtedly, the need to register the land use in a multipurpose land administrative system is urgent.

However, the unavailability of land use/cover data in any external source is a major problem all over the world with some exceptions in developed countries. In the case of availability, none standardized production is one problem and production of with different purposes in different data quality is the other. In fact, land use and land cover data are confused by the majority of spatial data users or even producers.

In this context, there are many different types of land use/cover classification systems for different purposes in different data quality and content, which are either designed internationally or nationally. CORINE land cover [EC, 1995] INSPIRE land use/cover themes [INSPIRE D2.8.II.2, 2013], land use capability classification [Soil Survey Staff, 1999], Land Parcel Identification Systems (LPIS) [Kay and Milenov, 2006; Goeman et al., 2007;Sagris et al., 2013] are a few international examples [Inan, 2013].

In LADM data model ExtLandUse and ExtLandCover classes were simply associated with LA_SpatialUnit. For the proposed model, the external class ExtLandUse was used in order to register the land uses for the cadastral parcels in Greece. The code list proposed is according to the corresponding land uses from the existing HC data model. It should be mentioned that the land uses registered at the HC are derived from the database of the corresponding Urban Planning department. Unfortunately, there is no frequently communication of the 2 databases and the values for land uses are not updated. This means that the system is not reliable and up-to-date as there are many changes through the years that are not registered. Additionally, the orthophotomaps used as basemaps from the HC also represent land uses, but they are dated back to 2008-2009 when was the last orthophotomaps created. Consequently, the introduction of this external class in the system is very important, as land uses affect also the value and the taxation of the land parcels, however the need for communication between the responsible authorities is urgent. Moreover, for the code list of the external land use type it should be mentioned that not only the values of the existing HC data model are included but also the values related to the different levels of spatial units.

It is evident naturally that any type of land use is spatially related to land parcel (and so GR_SpatialUnit class) in the case of a full partition data structure. In other cases, there may be some exceptions, yet this relation prevails. This relation is required for all types of Land Management activities such as land use planning and application, environmental protection schemes, rural development schemes and de-coupled payment schemes for farming land. That is to say, Land Administration should facilitate Land Management activities, which are related to land ownership, land use rights or merely land parcel boundaries.

External Land Use

◊ Code list ExtLandUseType

«codeList»
External::ExtLandUseType

+ LU01 - agriculture
+ LU02 - residential area
+ LU03 - industry
+ LU04 -nature
+ LU05 - recreation activity
+ LU06 - fishing activity
+ LU07 - forestry
+ LU08 - digging/minning
+ LU09 - no covered area
+ LU10 - energy
+ LU11 - services
+ LU12 - cultural activity
+ LU13 - sport activity
+ LU14 - tellecommunications
+ LU15 - Road network
+ LU16 - Railway network
+ LU17 - port
+ LU18 - airport
+ LU19 - parking area
+ LU20 - lake/canal
+ LU21 - coast
+ LU22 - beach
+ LU23 - coastal zone
+ LU24 - urban no built area
+ LU25 - storage area
+ LU26 - common space
+ LU27 - facilties for treating waste
+ LU28 - special use
+ LU29 - crossing
+ LU30 - station/stop for transportation means
+ LU31 - marsh
+ LU32 - open public space
+ LU33 - other
+ LU34 - pipeline installation
+ LU35 - space with archeological interest
+ LU36 - shipwreck
+ LU37 - research area

6.4.4. Ontology for the LC05 - SRPO

In the beginning the ontology SRPO_ontology is created and saved as OWL file. The main classes that are created are depicted in Figure 6.4 and they are subclasses of the super entity "Thing". Additionally, a small description for the ontology was added, as shown in Figure 6.2.

The entities created for the ontology are related to the spatial unit of the proposed model and their inter-relationships with the legislation framework of the country, the ways the SRPOs are represented in the existing HC and their attributes. Greece is considered as the basic entity after the top-level entity "Thing" and because the focus on the thesis is the land administration system, the next-level class is the National Spatial Data Infrastructure, which has as child the Land Administration System composed by the KAEK, the LADM and the representation objects. It should be noticed that the legislation framework was also added at the same level with the LAS as it is important in order to best describe the SRPOs. Its child are represented in Figure 6.3

Figure 6.2: Description of the SRPO_ontology.

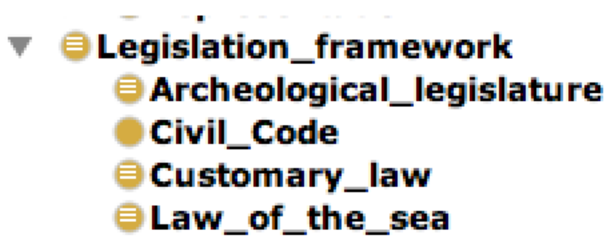


Figure 6.3: Children of the entity "legislation framework" in the SRPO_ontology.

As shown in Figure 6.4 the classes are based on the classes of the proposed model and is mainly focused on the spatial part. In particular, the different kinds of spatial units and the levels are analyzed and their relationships are depicted. The attributes of each one of the classes are most derived from the definitions of each one of the special real property objects, their inter-relationships and the customary law.

Additionally, for each one of the special property objects a definition is given (according to HC) as well as the relationship with the parcel or road that is related with and the special characteristics in case that it has (Figure 6.5).

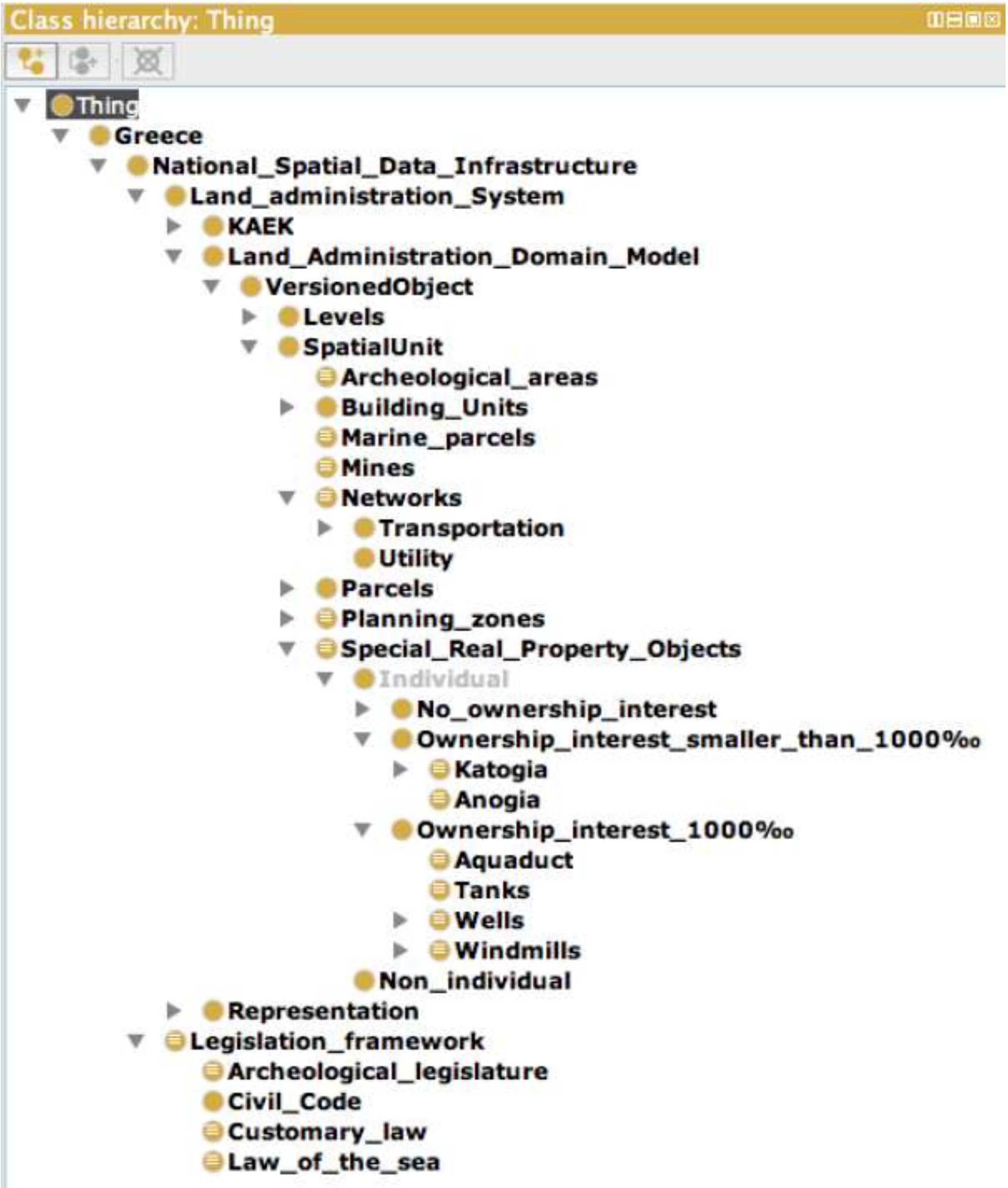


Figure 6.4: Basic classes created for the SRPO_ontology.

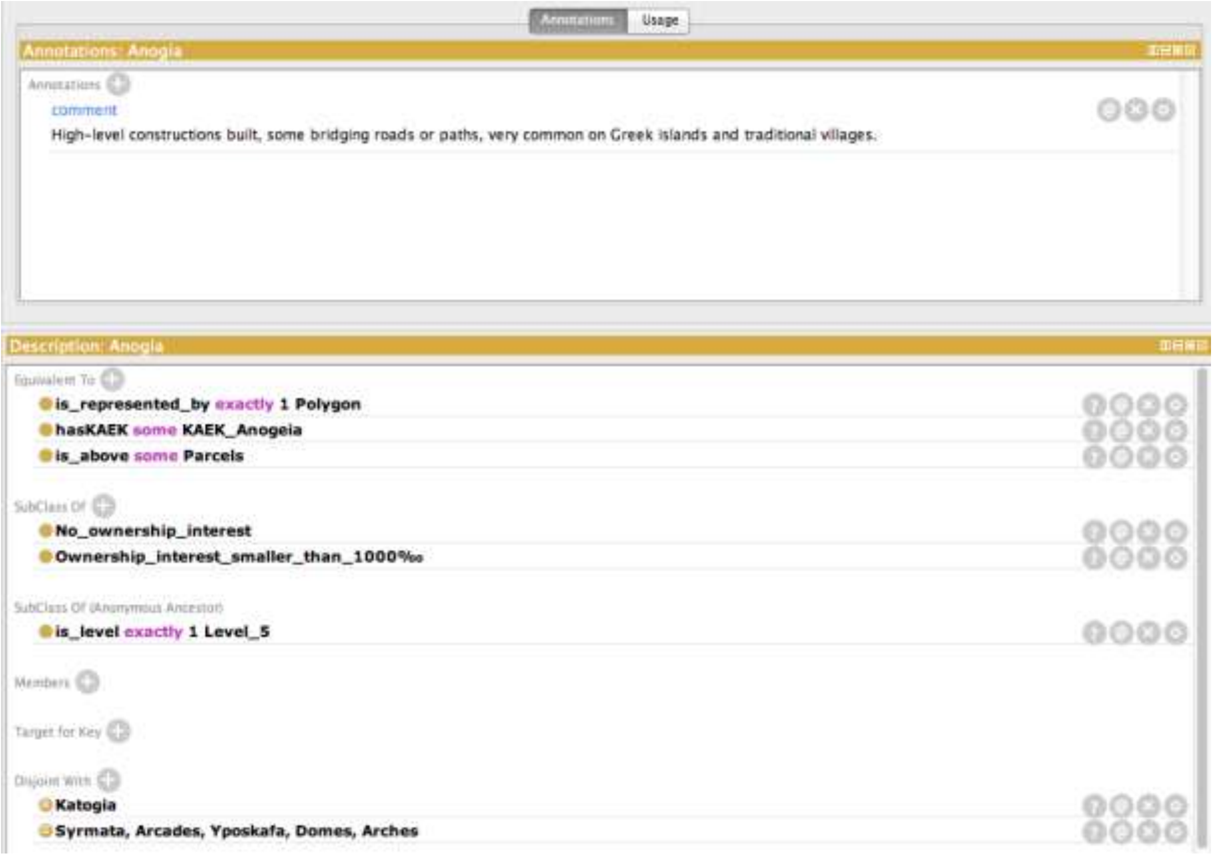
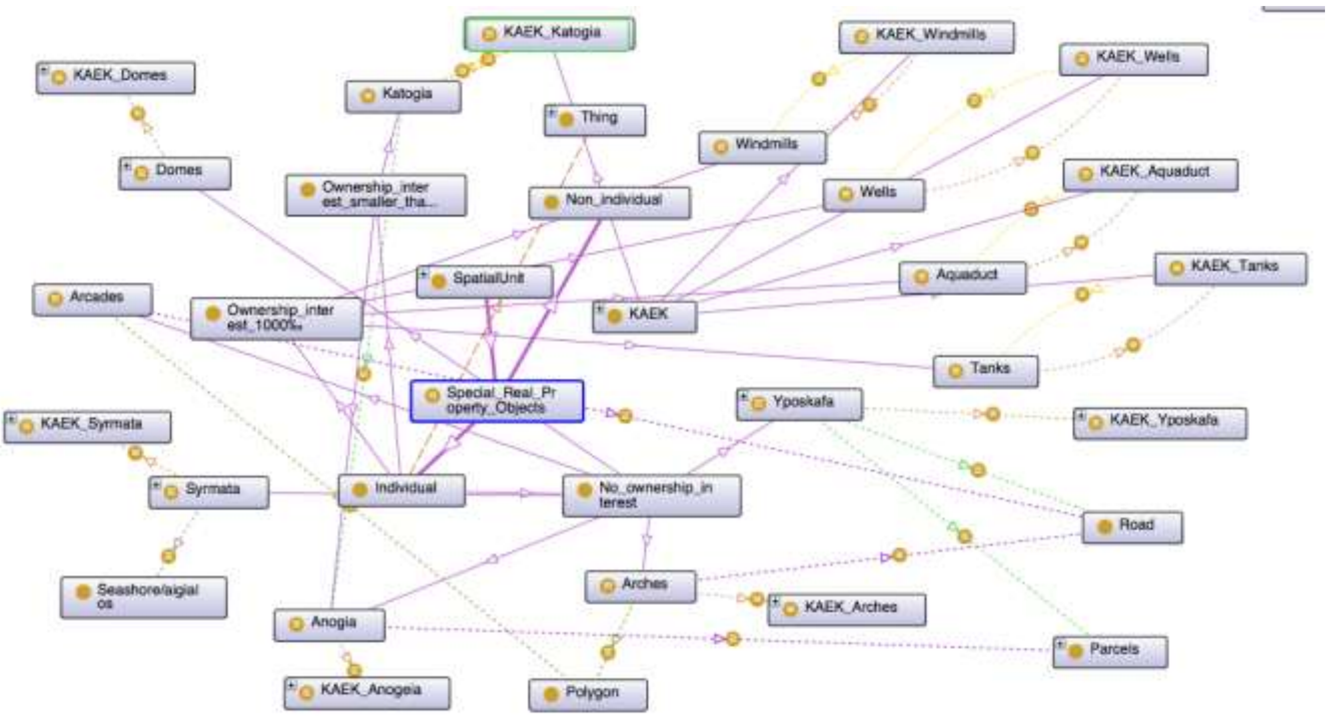


Figure 6.5: The definition and the attributes of the class "anogia".

As a first step, all the classes that are at the same level are disjoint with each other, an attribute that is related to the sub-classes of each class. Additionally, each one of the subclasses of the spatial unit is related with the corresponding level as proposed in the model.



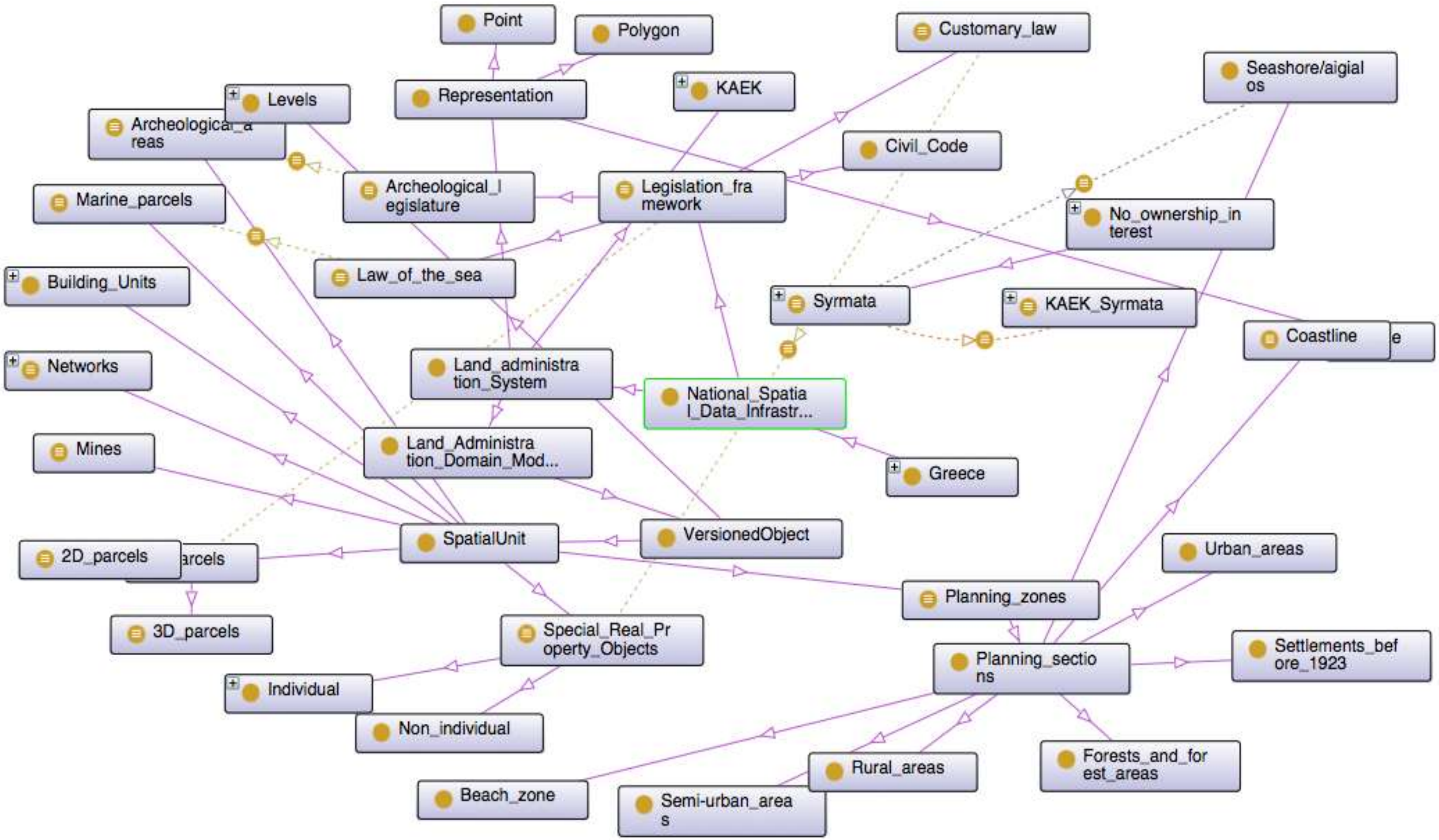


Figure 6.6: Basic entities of the SRPO_ontology at the top levels.

Last but not least, the planning zones are analyzed more in order to define the planning sections created in Greece, which is required for the description of the relationships of the SRPOs with the roads and/or the parcels. An example is presented in Figure 6.7

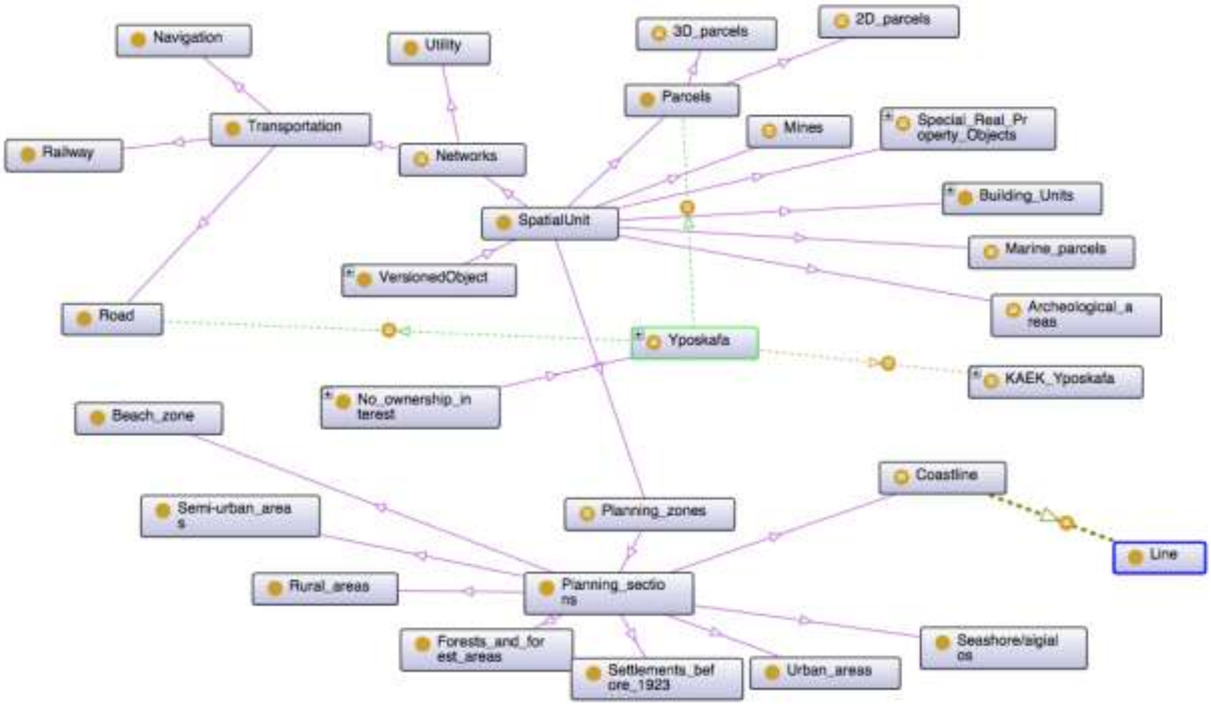


Figure 6.7: Example of the entity "yposkafa" and their relationship with the roads and the parcels.

Open World Assumption versus Closed World Assumption

Open World Assumption (OWA) assumes that the world has incomplete information. The statements that are not explicitly defined or cannot be inferred are not false, but undecided. Contrary, Closed World Assumption (CWA) assumes the world is complete; information that does not exist must be false (Zedlitz et. al, 2012). Semantic Web (Kolas et. al., 2005) and knowledge representation follow Open World Assumption, while software and database modeling supports Closed World Assumption. Because of the characteristics of OWA of being open, OWA has the capability to reveal new knowledge. In contrast, CWA supports consistency checking through constraints.

UML/OCL follows CWA while OWL applies OWA. Taking the example from the existing LADM model, an invariant such as

{Party can only have 0 RRR in case the party has specific role}

has been defined. If a database that has applied this invariant will be violated if the data that contain party information do not have related information about RRR and Role and that attempt to load in to the database. In contrast, if an ontology has defined a person that has spatial source and that does not have RRR as a surveyor, then when a person is detected to have spatial source and no related RRR, a reasoner would automatically infer that person as a surveyor (Soon, 2013).

6.5. Conclusions

The proposed Greek country profile both considers the current registration in 2D and the wishes for the future registration. For that reason, the third dimensions as well as different spatial units are also included in the proposed model LADM is capable of supporting the progressive improvement of cadastres, including both the geographic and other elements.

Referring to the proposed conceptual model in this chapter, LADM provides standardized class names for spatial and non-spatial data. For spatial data class, they have their own standard name called SpatialUnit. In the presented conceptual model, the Greek LADM country profile, GR_SpatialUnit has a number of specializations, explaining the multipurpose character of the model. Those are the archeological areas, the mines, the 2D and 3D parcels, the Special Real Property Rights, the legal spaces Utilities (3D), the marine parcels that are not yet included in the HC data model and the planning zones. The Building Unit is also divided into two subclasses, which are Building and the unfinished constructions.

Querying 2D spatial objects can be based on classes GR_2Dparcel and GR_PlanningZone. Meanwhile, GR_3Dparcel, GR_Network, GR_Mine, GR_MarineParcel, GR_SRPO and GR_Archeological would be used to query the 3D spatial objects. All geometry is obtained from GR_Point, which is associated with GR_SpatialSource.

GR_Party, including groups and subclasses of GR_RRR can be used to query non-spatial data. All administrative information is linked to administrative source documents, such as deeds, and included in the model via GR_AdministrativeSource.

The ID in each class is the important to link between spatial and non-spatial data. Additionally, the code lists for spatial and non-spatial data are proposed based on the characteristics of each class and the existing code lists of the HC data model. The coding in front of each code list value, e,g, PT01 – National strategic plan, is the unique identifier of the national strategic plan and should be used by all the responsible authorities, facilitating the exchange of information and the time querying the database and ensuring its accuracy and reliability.

Last but not least, the paper formalizes domain ontology for the Special Real Property Objects from the natural language definitions in the standard. The natural texts are a good source to provide a neutral stance for developing the ontology without a prior assumption like CWA or OWA. The development illustrated here, is just an initial step to define semantics for the Greek land administration system.

7. Conclusions and further research

The main research question of this thesis was "how to design a multipurpose cadastral model for Greece based on international standards". This thesis used the existing situation on the Hellenic Cadastre and the state-of the-art at the standardization domain as starting point, although international experience in LISs from other countries was examined. The emphasis of the thesis is on the creation of the conceptual model for Greece, based on the ISO 19152 Land Administration Domain Model [LADM].

To answer the main research question, the thesis concentrates on three main parts. This chapter lists the main conclusions that can be drawn from the three parts:

- Analysis of the background.
- Hellenic Cadastre.
- Proposed model for land management in Greece based on LADM.

This chapter aims to summarize the literature review for the 3D Cadastres and their different aspects as well as the state-of-the art on the standardization domain. For that reason, in the beginning, some general conclusions can be drawn from the overview of this thesis. Therefore the benefits and drawbacks of the proposed model based on LADM are analyzed. Finally, based on the conclusions recommendations for future directions and future research can be outlined.

7.1. General Conclusions

LAS in developed economies can promote sustainable development of the built and natural environments through public participation alongside informed and accountable government decision-making. The interface between the land administration infrastructure and professions and the public will expand as ICT helps implement e-government. Ultimately, e-government is e-democracy – allowing government of, by, and for the people through the use of the Web.

Nowadays many countries have developed their own LAS and they are not always willing and flexible to change according to the cadastral, technological and economic developments. The motivation to respond to change in any particular jurisdiction will depend on how local leaders and decision makers understand the importance of land management and the cadastre. The success of a cadastral system depends on how well it internalizes the new influences while achieving broader social, economic, and environmental objectives.

A 3D cadastre will assist in managing the effects of 3D development and increase the functionality of a multipurpose cadastre. It is important to realize that a 3D cadastre solution always depends on the local situation and is driven by user needs, land market requirements, the legal framework, and technical possibilities and there in no single best solution for a 3D cadastre. There are several questions that need to be answered for each country in order to investigate the special needs for 3D cadastre.

Nowadays more and more countries are moving towards the concept of a 3D cadastre. After past research and prototype developments, a new era has arrived with the first implementations and pilot programs of the first 3D cadastral systems in operation. It helps in communication to use existing standards when available [such as LADM] and to further discuss terminology and concepts. Due to the fact that the third dimension is important in the domain of land administration there is a growing interest in the technologies related to that.

In particular, 3D geo-database research is a promising field to support challenging application such as 3D urban planning, environmental monitoring, infrastructure management, to support the modeling, analysis, management, and integration of large geo-referenced data sets, which describe human activities and geophysical phenomena. Geo-databases may serve as platforms to integrate 2D maps, 3D geo-scientific models, and other geo-referenced data. Additionally, there are many 3D visualization systems for representing data in 3D, some researchers propose using CAD systems, other propose the use of GIS systems integrated with databases. However, these systems are still at a prototype level and require validation by users before being used in real applications. Moreover, much work still need to be done for the definition of 3D RRRs, their storage and representation.

The relationship between people and land (or space in case of 3D) is dynamic, which means that the temporal aspect of geo-data is fundamental for recording or monitoring changes, for describing processes, and for documenting future plans. Real world 3D dynamic cases (e.g. Australia) show requirements for a true 4D Cadastre as this reflects the real world situations. The fundamental question arises; should these 3D space, time and scale attributes of the cadastre be treaded separately, or is it worthwhile to deeply integrate these in a single higher dimensional representation. The last years in publications an additional dimension was used for the scale aspect. Recent researches have introduced 5D modeling, including the time and the scale as fundamental aspects of the geoinformation.

For the past decades LAS have managed to address cadastral issues within the boundaries of any country. However, recent advancements and requirements for a cross-boundary land administration require a common approach from the global and European community. For that reason, standards prove to be the best choice when it comes to Spatial Data Infrastructures and interoperability issues. This is the case with LADM.

Achieving semantic interoperability in the EU context is a relatively new undertaking, not achieved before. European Directives, and more specifically the INSPIRE Directive, set the legal framework for the creations of a European Spatial Data Infrastructure, where the cadastral information plays a basic role, as within any Spatial Data Infrastructure. So, standardization can be achieved by implementing one of those, or even both of these practices. It is then up to the country or the region to decide how to implement those.

The development of National SDI is an issue of significant importance also for Greece. A NSDI aims at the crossing boundaries between: organizations, countries and sectors; however it has as prerequisite interoperable data and services, which require the use of standards. Nowadays, multiple SDOs propose many different standards to support different activities. Standards for conceptual models, technical standards and specifications as well as communication protocols have been introduced in order to enable, facilitate and improve the maintenance and exchange of geographical information between different organizations in the same country or from different countries. Concluding, standardization and interoperability are gaining more strength in everyday transactions, thus LAS need to adopt them and adapt to them so that people and land can benefit from their advantages.

Land Administration Domain Model, ISO 19152, 2012 was selected among other standards to be the reference model for the proposed Greek model. The LADM provides standardized class names for spatial and non-spatial data and is therefore a good basis for national harmonization of land administration related information, maintained by various organizations. The unique identifiers form the important links between spatial and non-spatial data. Additionally, the external classes of LADM enable the link between the physical aspects of the object with the legal. For instance, at the LA_LegalSpaceUtilityNetwork the legal aspect of a gas pipeline will be described. The model enables the connection with an external class, extPhysicalUtilityNetwork that is a reference to the physical, technical description of the pipeline.

LADM contains the collective experience of experts from many countries [in ISO and FIG] as it took long time to develop. In general it is a good practice to learn from other countries before implementing specific new functionality into the system Last but not least, LADM is compatible with many other ISO standards and makes use of a number of concepts and classes from other ISO TC211 standards, enabling the interoperability with other organizations without the need of multiple transformations, which lead to loss of information.

The Hellenic Cadastre [HC] is a unified and constantly updated system of information that records the legal, technical and other additional details about real estate properties and the rights on them; which is still in an ongoing process.

The need for 3D registrations and representation in Greece is vital concerning special cases like the multilevel constructions, the overlapping properties and the SPROs. A successful 3D Cadastre for Greece will constitute a unique tool, a level for sustainable development in urban and land planning and in every aspect of technical, financial, social and legal issues of everyday life. It can also be used as a means for political decisions and pressure, which is nowadays a key challenge for the Greek reality.

The characteristic cases, which require 3D registration are presented in 5.7 and is concluded that the hybrid model seems to be the best solution for the Greek case. The key issue and main drawback concerning the development of the Greek Cadastre is that it is basically legal. It is quite obvious that Greek legislation contains contradictory laws on property rights, which is rather confusing. Therefore there is a need to perform relevant reforms and adjustments in order to tackle this situation.

However, Greece has made a first step forward when the Ktimatologio S.A. and HEMCO were merged into one unique organization, the NCMA S.A., like the Kadaster in the Netherlands, the Cadastral Office in Belgium, etc. responsible for both the collection of all the geographical information and the registration of the legal rights on them. Additionally, during the cadastral surveys a special adjudication procedure is been followed and parallel infrastructure projects are carried in order to facilitate the progress of the project.

To sum up, the third dimension needs to be incorporated into [some] cadastral registrations; however, several modifications to the actual property rights' registration procedure are required. Therefore, it is vital to consider fundamental issues of the operating HC, such as the fact that the outlines of any construction are not represented on the cadastral map.

7.2. Evaluation of the proposed model

7.2.1. Advantages of the proposed model

Under these circumstances it is clear that it's not yet possible to adopt a full 3D cadastral system, therefore the hybrid 3D model seems to be feasible and the optimal solution for the Hellenic Cadastre. Besides, referring to a hybrid conceptual model, it involves the maintaining of the current 2D Cadastre, while simultaneously incorporating the registration of three-dimensional cases and the integration of 3D data types in every case necessary.

It may be wise to design a more generic solution, from legal, organizational and technical points of view, of which initially only the most urgent cases will be represented in 3D. However, it is to be expected that in less urgent cases the needs or expectations of society in the future may also change and it is wise to anticipate or even stimulate these future uses of 3D registration e.g. registration of airspace or the registration of apartments in 3D.

This was one of the main reasons the proposed model divides the Spatial Unit into different levels according to their thematic and geometric coherence.

The 8 levels that are described enable the best organization and exploitation of the spatial and non-spatial information of each level. GR_2Dparcel and GR_PlanningZone are the only two levels with a two dimensional nature. The rest are described with three dimensions. Apparently, apartments or condominiums are the most frequent type of 3D objects to which RRRs are attached, and it could be argued that these are managed quite well even without a 3D Cadastre today. However, a 3D Cadastre would provide easier to use representations. In addition, there are occurring more and more complicated cases where the condominium needs to be connected to a 3D volume (above or below the surface) from an adjoining parcel. This is nowadays often solved in a suboptimal way (e.g. a lease, but unaptly describing the proprietary relationships and rights), and a 3D Cadastre solution would clearly bring benefits.

Additionally, the code lists for spatial and non-spatial data are proposed based on the characteristics of each class and the existing code lists of the HC data model. The coding in front of each code list value, e,g, RP07 –Architectural building conservation, is the unique identifier of responsibility of the corresponding party for the conservation of an architectural building. This serial number should be unique at the national level and used by all the responsible authorities, facilitating the exchange of information and the time querying the database and ensuring its accuracy and reliability.

This intends to create a database with national code lists that can be easily managed and updated by one responsible authority. The use of code lists and their corresponding serial number enables the communication between the different organizations and responsible authorities.

The introduction of the marine parcel is an initiative as it is not included to the current model. Towards a multipurpose land administration system and the fact that a big part of the Greek territory is covered by water there is a need to implement a maritime spatial planning. According to the EU each MS is free to plan its own maritime activities, local, regional and national planning in shared seas under a set of minimum common requirements. Consequently, the introduction of the marine parcel was important. The registration of marine interests will allow the country to govern effectively the tenure in the marine environment. With the introduction of marine space in the proposed model, the registration of interests where Greece has sovereign rights is completed.

Additionally, the introduction of the planning zones was important. The different levels of spatial planning in Greece exist today and different authorities manage them. Including them in the land administration system enables the comparison between what it was plan to be done and what is actually done and also facilitates future planning according to the needs of each area.

7.2.2. Limitations of the proposed model

It is very difficult to create and maintain such a multipurpose system. All the spatial and non-spatial information should be described and stored in specific and compatible formats allowing the meaningful exchange of information and avoid the transformations. This requires many changes at the organizational and technical part of all the involved authorities, increasing the complexity of the LAS.

Such a system also requires the direct communication between the different authorities, organizations and institutions, fact that does not reflect the existing situation. A significant change is needed in the way those authorities are organized and communicate with each other. Additionally, the updates at the different datasets are crucial as well as the link between them and the main database of the multipurpose LIS through the external classes. Only when the main database is up-to-date the system can be characterized by valid, accurate and transparent registrations and transactions.

For those general limitations and much more specific regarding the characteristics of each class, this model is a research proposal based on an international ISO towards the creation of a multipurpose LIS. Further research is needed.

7.3. Further research

There are many aspects of the 3D cadastre that need to be further explored and many related activities worldwide that need to be upgraded from 2D to 3D representations. The chain of those activities requires good information flows between the various actors. It is crucial that the meaning of this information is well defined as it is an important role for standardization and interoperability. Therefore, more formal semantics are requested within the 3D cadastre domain. For example, an ontology should be further developed in OWL (or RDF) for 3D land administration based on the foundation of ISO 19152. Finally, there is a need to create National or International Organizations for the semantics that will create, maintain and update terminology, definitions and ontologies for the spatial data.

At the same time, it is proposed that a more international comparative legal research should be conducted, although there are many differences in national legislation and terminology. This will facilitate the definition of semantics and ontology in the domain of land administration.

From a more technical side, it is a key challenge today to find-out the benefits and drawbacks of the different 3D geometries and exchange formats and the applications for which each one is more suitable. Additionally, it is important to define formal validity of parcel with mixed geometry (2D & 3D). This will lead to less complex structures which can be easier be stored and also visualized.

Meaningful communication is enabled by using existing standards where available and by further discuss shared concepts between the countries. LADM can be a basis for combining data from different LASs, e.g. LASs with datasets describing People to land relationships. It opens options now to bridge gaps between cultures where People to Land relationships are concerned, having a more social role. Its aims are equally valid for both developed and developing countries, which also lead to the development of a more specialized model called the Social Tenure Domain Model (SDTM).

The connection between other organizations is made as LADM makes use of unique identifiers forming links between spatial and non-spatial data. In order to gain the best out of the standardization and interoperability process, the majority of the countries should agree on certain legal aspects. In the case of LADM this would be a common code list for a cross-boundary approach. The identifiers should not only be unique within a single organization, but should be globally unique and can be used in the context of the national SDI to realize references to objects in each others registrations. In the future there may be a global (ISO or FIG or OGC) organization, maintaining code list and their values. Other constrains need to be addressed as well, for example the maintenance and updating of data, as this makes a land administration system more reliable and secure.

7.3.1. Proposed model

Further research should be done for the external class for land use. Association of land use data sets with land parcels is required for any related land management activity. Therefore, checking the updateness of associated land use data with other external data sources – a satellite image or similar cartographic material is an important aspect. However, there are many different types of land use classification systems for different purposes in different data quality and content and the content of external data sources may require a generalization process before processing the data for the association. In case of a general land use classification within external data, it may not be possible specializing land use classes without using any additional external data – satellite imagery or similar cartographic material. A recent study for the association of external land use and cover information with LADM is done by Inan [2013].

Additionally, research for technical issues concerning the compatibility of different types of databases and formats should be done in order to facilitate the communication of the different authorities. Research is also necessary for developing ontologies for the proposed land administration system. As it is very different to define semantics and ontologies in an international and even in national level, it is considered important to develop a detailed ontology for each one of the different levels of the spatial part, as well as an ontology for the administrative part of the model and find the ways those ontologies communicate with each other in order to create shared concepts and terminology for a LAS in Greece.

Moreover, as the marine parcel is introduced as a separate level, the air parcel can also be added as a separate level for future development of the proposed multipurpose LAS.

Finally, future work includes assessment of the proposed model, mostly for enriching the code lists, before taking further implementation decisions. For this purpose a prototype system should be developed in order to discover the possibilities and limitations of the conceptual model. Experience from the prototype development will be used to further improve the conceptual model.

The steps in developing this prototype include:

- **Derive the technical model** [Oracle Spatial or PostGIS] **from the conceptual model:** from UML diagram move to database tables SQL DDL scripts for data storage [and/or XML schema for exchange format according to LandXML/ InfraGML, CityGML, BIM/ IFC], For this purpose the Swiss standard INTERLIS can be used. INTERLIS can be used as a Conceptual Schema Language or a neutral Transfer Format as it is a very precise, standardized language on the conceptual level to describe data models. It also enables the conversion from UML to exchange formats or database schema; and this is the option that should be further explored. Implement the proposed model in INTERLIS using UML diagrams and create a first database schema and also a transfer format, probably in XML.
- **Convert some** [and/or create] **sample data into the proposed model:** this covers both spatial and non-spatial data, and should also include selection for the 3D cases, which are to be supported by the future 3D Cadastre, and
- Develop frontends to view and edit for professional desktop access, and also develop an appropriate web-interface for SOI/LR/ILA data access.

References

Abdul Rahman, A., Teng, Chee Hua and Van Oosterom, P.J.M. (2011). "Embedding 3D Into Multipurpose cadastre". In: FIG Working Week 2011 - Bridging the Gap between Cultures. Marrakech, Morocco.

Adeniran T., 2014. Office of the Surveyor General of the federation of Nigeria

Aditya, T., Iswanto, F., Wirawan, A. and Laksono, P. D. (2011). "3D Web Cadastre Web Map: Prospects and Developments". 2nd international Workshop on 3D Cadastres.

Agarwal, P. (2005). "Ontological Considerations in GIScience". In: International Journal of Geographical Information Science, 19 (5).

Aien, A, Kalantari, M., Rajabifard, A., Williamson, I., Wallace, J., (2013). "Towards integration of 3D legal and physical objects in cadastral models". In: Land Use Policy, 35.

Aien, A., Kalantari, M., Rajabifard, A., Williamson, I., Bennett, R., (2013). "Utilizing data modeling to understand the structure of 3D cadastres". In: Journal of Spatial Science, 58(2).

Augustinus, C., (2010). "Social Tenure Domain Model: What It Can Mean for the Land Industry and the Poor". XXIV FIG International Congress. Sydney, Australia.

Augustinus, C., C.H.J. Lemmen and P.J.M van Oosterom, (2006). "Social Tenure Domain Model – Requirements from the perspective of pro-poor land management". 5th FIG Regional Conference - Promoting Land Administration and Good Governance, Accra, Ghana.

Benhamu, M. and Doytsher, Y. (2003). "Toward a spatial 3D cadastre in Israel." Computers, Environment and Urban Systems 27 (4).

Bertin, J. (1983). "Semiology of graphics: diagrams, networks, maps".

Binns, A. and I. Williamson (2003). "Building a National Marine Initiative through the Development of a Marine Cadastre for Australia". Proceedings of the South Asian Seas Congress, Malaysia.

Bogaerts, T. and J. Zevenbergen (2001). "Cadastral Systems: alternatives". Computers, Environment and Urban Systems, 25 (4-5).

Boskovic, D., Ristić, A., Govedarica, M., & Pržulj, D. (2010). "Ontology development for Land Administration". In Proceedings of 8th International Symposium on Intelligent Systems and Informatics (SISY).

Budisusanto Y., Aditya, T. and Muryamto, R., (2013). "LADM implementation prototype for 3D Cadastre Information System of Multi-Level apartment in Indonesia".5th Land Administration Domain Model Workshop. Kuala Lumpur, Malaysia.

Charisse Griffith-Charles & Michael Sutherland. (2014). "Governance in 3D, LADM Compliant Marine Cadastres". In: Proceedings of the 4th International Workshop on 3D Cadastres, 9-11 November 2014, Dubai, United Arab Emirates.

Cockburn, S., Nichols, S. and Monahan, D. (2003). "UNCLOS Potential Influence on a Marine Cadastre: Depth, Breadth, and Sovereign Rights", In: Proceedings of the Advisory Board on the Law of the Sea to the International Hydrographic Organization (ABLOS) Conference "Addressing Difficult Issues in UNCLOS."

Commission of the European Communities (2000), "The EU compendium of spatial planning systems and policies. Greece" Regional development studies, 28 G, Luxembourg: CEC

De Vries, M., and Zlatanova, S. (2004). "Interoperability on the Web: the case of 3D geo-data". In: Proceedings IADIS International Conference e-Society, Avila, Spain.

De Laat, R. and van Berlo, L. (2011). "Integration of BIM and GIS: The development of the CityGML GeoBIM extension". In Advances in 3D Geo-Information Sciences (pp. 211-225). Springer Berlin Heidelberg

Dimopoulou, E. and Gogolou, C, (2013) "LADM as a basis for the Hellenic Archeological cadastre". 5th Land Administration Domain Model Workshop. Kuala Lumpur, Malaysia.

Dimopoulou, E. and Elia, E. (2012). "Legal aspects of 3D property rights, restrictions and responsibilities in Greece and Cyprus". In Proceedings of the 3rd International Workshop on 3D Cadastres, Developments and Practices.

Dimopoulou, E., Gavanas, I., Zentelis, P. (2006). "3D Registrations in the Hellenic Cadastre". In: TS 14-3D and 4D Cadastres, Shaping the Change XXIII FIG Congress. Munich, Germany.

Döner F., Thompson R., Stoter J., Lemmen C., Ploeger H., van Oosterom P.J.M. and Zlatanova S. (2011). "Solutions for 4D cadastre - with a case study on utility networks". In: International Journal of Geographical Information Science, 25.

EC (European Commission), [1995]. CORINE Land Cover
(at http://www.eea.europa.eu/publications/COR0-landcover).

El-Mekawy, M., & Östman, A. (2010). "Semantic mapping: an ontology engineering method for integrating building models in IFC and CityGML". In: Proceedings of the 3rd ISDE Digital Earth Summit.

El-Mekawy, M., Östman, A., & Hijazi, C. (2011a). "An Evaluation of the IFC-CityGML Unidirectional Conversion". In: International Journal of Advances Computer Sciences and Applications, Vol3, No5.

El-Mekawy, M., Östman, A., & Hijazi, C. (2011b). "A Unified Building Model for 3D Urban GIS". In: International Journal of Geo-Information.

El-Mekawy, M., Östman, A., & Shahzad, K. (2011). "Towards interoperating CityGML and IFC building models: a unified model based approach". In: Advances in 3D Geo-Information Sciences.

Elizarova, G., Sapelnikov, S., Vandysheva, N., Pakhomov, S., van Oosterom, P., de Vries, M., Stoter, J., Ploeger, H., Spiering, B., Wouters, R., Hoogeveen, A., Penkov, V. [2012]. Russian-Dutch Project "3D Cadastre Modelling in Russia", 3rd International Workshop on 3D Cadastres: Developments and Practices 25-26 October 2012, Shenzhen, China

Elia E., Zevenbergen A.J., Lemmen, C. H. and Van Oosterom J.M. P. [2011]. "The land administration domain model (LADM) as the reference model for the Cyprus land information system (CLIS)". Survey Review, 45 [329].

FAO, (2002). "Land Tenure and Rural Development". FAO Land Tenure Studies. Rome, Italy

Falkowski , K., Ebert , J., Decker , P., Wirtz , S., Paulus, D. [2009]. "Semiautomatic generation of full CityGML models from images". In: Geoinformatik 2009, 35. Institut fur Geoinformatik Westfàlische Wilhelms-Universität.

Felus, Y., Barzani, S., Caine, A., Blumkine N. and van Oosterom P.J.M. [2014]. "Steps towards 3D Cadastre and ISO 19152 (LADM) in Israel". 4th international Workshop on 3D Cadastres. Dubai, United Arab Emirates.

FIG, [2010]. Questionnaire 3D-Cadastres: status September 2010, FIG joint commission 3 and 7 working group on 3D-Cadastres – Work plan 2010-2014, International Federation of Surveyors (http://www.gdmc.nl/3DCadastres/.FIG/GLTN 2010)

FIG [2014]. "FIG Guide – Fit – For – Purpose Land Administration", Joint FIG/World Bank Publication.

Fraser, R., Todd, P. J. and Collier, P.A. (2003). "Issues in the Development of a Marine Cadastre. Addressing Difficult Issues in UNCLOS". ABLOS Conference, Monaco

Frédéricque, B., K. Raymond van Prooijen (2011). "3D GIS as Applied to Cadastre – A Benchmark of Today's Capabilities". FIG Working Week 2011, Marrakech, Morocco.

Fulmer, J. (2007). "The multipurpose marine cadastre web map". In: Proceedings of the 2007 ESRI Surveying and Engineering GIS Summit, San Diego.

Greek Civil Code

GMEA [2006]. "Importance of the implementation of the Code of Principles of sustainable development in the Greek mining industry". In: Proceedings of GMEA meeting.

Goeman, D., Kantor, C., Printzios, V., Zloty A. and Mercimek, E. [2007]. "Final Report for Technical Assistance for the Ministry of Agriculture and Rural Affairs for the Design of a Functioning Integrated Administration and Control System (IACS) and a Land Parcel Identification System (LPIS) in Turkey" The European Union's TR0402.08/002 Program for Turkey, Ankara.

Goetz, M., & Zipf, A. (2011). "Extending OpenStreetMap to indoor environments: bringing volunteered geographic information to the next level". CRC Press: Delft, The Netherlands.

Gröger, G., Kolbe, T.H., Nagel, C., Häfele, K.,H. [2012]. "OpenGIS City Geography Markup Language (CityGML) Encoding Standard – Version: 2.0. Open Geospatial Consortium Inc.

Greenway, I. (2005). " Why Standardise?" 5th FIG Regional Conference Accra, Ghana.

Guo, R., Li, L., Ying, S., Luo, P., He, B., and Jiang, R. (2013). "Developing a 3D cadastre for the administration of urban land use: A case study of Shenzhen, China". Computers, Environment and Urban Systems, 39 (2).

Guo, R.; Ying, S.; Li, L.; Luo, P. and Van Oosterom, P (2011). "A Multi-jurisdiction Case Study of 3D Cadastre in Shenzhen, China as Experiment using the LADM". In: proceedings 2nd International Workshop on 3D Cadastres, 2011. Delft, The Netherlands.

Guo R, Yu C, He B, et al 2012. "Logical Design and Implementation of the Data Model for 3D Cadastre in China". In: Proceedings 3rd International Workshop on 3D Cadastres: Developments and Practices.

Hamilton, A., Wang, H., Tanyer, A. M., Arayici, Y., Zhang, X., & Song, Y. H. (2005). "Urban information model for city planning". Journal of Information Technology in Construction (ITCon).

Hassan, M.I. and Abdul-Rahman, A. [2010]. "An integrated Malaysian cadastral system. FIG Congress 2010. Sydney, Australia.

Hespanha, J.P., (2012) [PhD thesis]. "Development Methodology for an Integrated Legal Cadastre - Deriving Portugal Country Model from the Land Administration Domain Model". Delft University of Technology, Delft, the Netherlands

Henssen, J., [1995]. "Basic Principles of the Main Cadastral Systems in the World Seminar Modern Cadastres and Cadastral Innovations". Delft, The Netherlands.

Hijazi, I., Zlatanova, S., & Ehlers, M. (2011). "NIBU: An integrated framework for representing the relation among building structure and interior utilities in micro-scale environment". Geo-spatial Information Science, 14 (2).

Ho S. [2012]. "Delivering 3D Land and Property management: a consideration of institutional challenges in an Australian context". Shenzhen, China

Ho S., Rajabifard A., Stoter J. and Kalantari M. [2013]. "Legal barriers to 3D Cadastres implementation: What is the issues?" In: Land use policy, 35.

Hoogsteden, C.C., and Robertson, W.A. (1998). "On Land, Off Shore: Strategic Issues in Building a Seamless Cadastre for New Zealand", Proceedings of XXI International Federation of Surveyors Commission 7 Congress, Brighton, UK.

Hoekstra, R. (2010). "Representing Social Reality in OWL 2". In Proceedings of the 7th International Workshop on OWL: Experiences and Directions (OWLED 2010), San Francisco, California, USA, 2010

IFC (2012). "Industry Foundation Classes Release 2x4 (IFC4) Release Candidate 3 Specification", at: http://buildingsmart-tech.org/ifc/IFC2x4/rc3/html/index.htm

Inan, I., H. [2013] "Associating External Land Use/Cover Information with LADM's Spatial Unit" In: Proceedings 5th Land Administration Domain Model Workshop, Kuala Lumpur, Malaysia

INSPIRE, (2007). Directive 2007/2/EC of the European Parliament establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).

INSPIRE (2009). "D2.8.I.6 INSPIRE Data Specification on Cadastral Parcels – Guidelines".

INSPIRE [2013]. "D2.8.II.2 INSPIRE Data Specification on Land cover – Draft Technical Guidelines" (at http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_LC_v3.0rc3.pdf).

Isikdag, U., Aouad, G., Underwood, J., & Wu, S. (2007). "Building information models: a review on storage and exchange mechanisms". Bringing ITC Knowledge to Work.

Isikdag, U., Underwood, J., & Aouad, G. (2008). "An investigation into the applicability of building information models in geospatial environment in support of site selection and fire response management processes". Advanced engineering informatics, 22 (4).

Isikdag, U., Zlatanova, S., [2009]. "A SWOT analysis on the implementation of Building Information Models within the geospatial environment". In: Proceedings of the Urban Data management Society Symposium 2009,Ljubljana, Slovenia.

Isikdag, U., Zlatanova, S., and Underwood, J. (2013). "A BIM-Oriented Model for supporting indoor navigation requirements". Computers, Environment and Urban Systems, 41.

ISO, [2012] "ISO 19152:2012. Geographic Information - Land Administration Domain Model (LADM)".

Iván, G. [2011]. "3D cadastre development in Hungary". In: Proceedings of the Second International Workshop on 3D Cadastres. Delft. The Netherlands.

Jarroush, J. and Even-Tzur, G. [2004]. "Constructive Solid Geometry as Basis of 3D Future Cadastre". FIG Working Week 2004. Athens, Greece.

Kalantari, M. and Rajabifard, A. [2014]. "A roadmap to accomplish 3D Cadastres". 4th International Workshop on 3D Cadastres, Dubai, United Arab Emirates.

Kalantari, M., Rajabifard, A., Urban-Karr J., and Dinsmore K. (2013). "Bridging the Gap between LADM and Cadastres". In: Proceedings of the 5th FIG Land Administration Domain Model Workshop, Kuala Lumpur, Malaysia.

Kalogianni, E., Dimopoulou, E. (2014). "Design of a model for managing the public property in Greece". In: Geomapplica 2014 - 1st International Geomatics Application Conference, Skiathos Island, Greece.

Karki, S., Thompson, R. and McDougall, K. (2010). "Data Validation in 3D Cadastre". Advances in 3D Geo-information Sciences, XIV.

Kaufmann, J., Steudler, D., 1998. "Cadastre 2014, A vision for future cadastral system" with the Working Group 1 of FIG Commission 7.Kaufmann, 1999.

Kavvadas, I. (2012) "Greek Cadastre Quality Model and Quality Checkink of spatial cadastral data". In: www.ktimatologio.gr/Documents/Pages/2844/edu_material/1590.pptx+&cd=8&hl=en&ct=clnk&gl=gr

Kay, S. and Milenov, P. (2006). "Status of the Implementation of LPIS in the EU Member States" In: 12th MARS PAC Annual Conference, Toulouse, France.

Kemec, S., Zlatanova, S., & Duzgun, S. (2009). "Selecting 3D urban visualisation models for disaster management: a rule-based approach". In: Proceedings of TIEMS 2009 Annual Conference.

Kim, T.J., Lee, B.M. and Lee, Y.H. (2013). "A Strategy for Developing the Cadastral System of Cadastral Resurvey: Project based on International Standard (LADM) in South Korea". In: Proceedings of the 5th FIG Land Administration Domain Model Workshop. Kuala Lumpur, Malaysia.

Kitsakis, D. and Dimopoulou, E. (2014). "3D Cadastres: Legal Approaches and Necessary Reforms". Survey Review, 46 (338).

Kitsakis, D. and Dimopoulou, E. (2014). "Contribution of Existing Documentation in 3D Cadastres". 4th International Workshop on 3D Cadastres, Dubai, United Arab Emirates.

Kokla, M., & Kavouras, M. (2001). "Fusion of top-level and geographical domain ontologies based on context formation and complementarity". International Journal of Geographical Information Science, 15(7).

Kolas, D., Hebeler, J. and Dean, M. (2005). "Geospatial Semantic Web: Architecture of Ontologies". In: Rodriguez, M. A., Cruz, I., Levashkin, S. and Egenhofer, M. (Eds): Geospatial Semantics 2005, Lecture Notes in Computer Science, 3799.

Kolbe, T., H., (2009). "Representing and Exchanging 3D City Models with CityGML".In: Proceedings of the 3rd International Workshop on 3D Geo-Information, Seoul, Korea.

Laat de, R. and van Berlo, L. (2011). "Integration of BIM and GIS: The Development of the CityGML GeoBIM Extension", Advances in 3D Geo-information Sciences, XIV.

Lee, J., and Zlatanova, S. (Eds.), (2009). "3D geo-information sciences". Springer.

Lemmen, C., (2012) (PhD thesis). "A Domain Model for Land Administration". Delft University of Technology, Delft, The Netherlands.

Lemmen, C. H., Van Oosterom, P.J.M, R. J. Thompson, J. Hespanha and H. T. Uitermark (2010a). "The modelling of spatial units (parcels) in the Land Administration Domain Model (LADM)". XXIV FIG International Congress. Sydney, Australia.

Lemmen, C. H.,. and Van Oosterom, P.J.M (2013). "The Land Administration Domain Model Standard". 5th Land Administration Domain Model Workshop. Kuala Lumpur, Malaysia.

Lemmen, C.H.J., Augustinus, C., van Oosterom, P.J.M. and van der Molen, P., (2007). "The social tenure domain model: design of a first draft model". FIG Working week 2007: strategic integration of surveying services. Hong Kong SAR, China.

Lemmen, C.H., Zevenbergen, J., Lengoiboni, M., Deininger. K. and Burns, T. . (2009). "First experience with High-resolution imagery based adjudication approach for a social domain model in Ethiopia". FIG – World Bank Conference Land Governance in Support of the Millennium Development Goals – Responding to New Challenges Washington D.C., USA.

Mark, D., Smith, B., Egenhofer, M., and Hirtle, S. (2004). "Ontological Foundations for Geographic Information Science". In McMaster, R. B., and Usery, E. L. (Eds), A Research Agenda for Geographic Information Science. CRC Press

Metral, C., Falquet, G., and Karatzas, K. (2012). "Ontologies for the integration of air quality models and 3D city models". arXiv preprint arXiv:1201.6511.

Métral, C., Ghoula, N., and Falquet, G. (2012). "Towards an Integrated Visualization Of Semantically Enriched 3D City Models: An Ontology of 3D Visualization Techniques". arXiv preprint arXiv:1202.6609.

Mattheou, E. (2004). "Report on the Greek Civil Code".

Meinzen-Dick, R.S.and Pradhan, R., (2002). "Legal Pluralism and Dynamic Property Rights. Collective Action and Property Rights Working Paper 22". International Food Policy Washington, D.C., U.S.A.

Miguel, J., García, O., Ignacio, L., Soriano, V. and Martín-Varés, A. V. (2011). "3D Modeling and Representation of the Spanish Cadastral Cartography". In: Proceedings of the 2nd International Workshop on 3D Cadastres, Delft, Netherlands.

MMSD Project (2002). (a) Mining for the future, (b) Sustainability indicators and sustainability performance managemen

Nagel, C., Stadler, A., Kolbe, T.H. (2009). "Conceptual requirements for the automatic reconstruction of building information models from uninterpreted 3d models". At: http://www.isprs.org/proceedings/xxxviii/3_4-c3/paper_geow09/paper26_nagel_stadler_kolbe.pdf)

NASA, (2005). "Geospatial Interoperability Return on Investment Study". National Aeronautics and Space Administration, Geospatial Interoperability Office, April 2005.

National Defence of Canada (2012). "Open BIM and the future: BIM and GIS integration - Building the DND Real Property Spatial Data Framework".

Ng'ang'a, S. M., M. Sutherland, S. Cockburn and S. Nichols (2004). "Toward a 3D marine cadastre in support of good ocean governance: A review of the technical framework requirements". In Computer, Environment and Urban Systems, 28.

Navratil, G. and Unger, E.-M. (2013). "Requirements of 3D Cadastres for Height Systems". Computers, Environment and Urban Systems, 38.

NBIMS, (2006) National BIM Standard Purpose, US National Institute of Building Sciences Facilities Information Council, BIM Committee, (at: http://www.nibs.org/BIM/NBIMS_Purpose.pdf).

Nebert, D. (2001). "Developing Spatial Data Infrastructures: The SDI Cookbook, version 1.1".

Nichols, S., S. Ng'ang'a, M. Sutherland, and S. Cockburn (2006). "Chapter 10. Marine cadastre concept". In Canada's Offshore: Jurisdiction, Rights and Management, 3rd edition, Eds., Bruce Calderbank, Alec M. MacLeod, Ted L. McDorman and David H. Gray, Victoria: Trafford Publishing, 2006, ISBN 1-4120-7816-4.

OGC, (2014). "OGC and buildingSMART International developing InfraGML, a new standard for land and infrastructure information". At: http://www.opengeospatial.org/blog/2098.

Osskó, A. (2001). "Problems in registration in the third vertical dimension in the unified Land Registry in Hungary, and possible solution". In: Proceedings of the International Workshop on 3D Cadastres, 2001, Delft, The Netherlands.

Paasch, J.M., Paulsson, J., (2011). "Terminological aspects concerning three-dimensional real property". Nordic Journal of Surveying and Real Estate Research, 8.

Papaefthymiou, M., Labropoulos, T., Zentelis, P. (2004). "3D cadastre in Greece-Legal, Physical and Practical Issues Application on Santorini Island". In: TS 25-Appropriate Technologies for Good Land Administration II-3D Cadastre, FIG Working Week 2004. Athens, Greece.

Paulsson, J., (2007) (PhD thesis). "3D Property Rights – An analysis of key factors based on International Experience". Royal Institute of Technology (KTH), Stockholm, Sweden.

Paulsson, J. (2012). "Swedish 3D Property in an International Comparison". 3rd International Workshop on 3D Cadastres: Developments and Practices, Shenzhen, China.

Pouliot, J. (2011). "Position Paper 4: Visualization, Distribution and Delivery of 3D Parcels". In: In: Proceedings of the 2nd International Workshop on 3D Cadastres, Delft, Netherlands,

Pouliot J., Marc V., Abbas B. (2011). "Spatial Representation of Condominium/Co-ownership: Comparison of Quebec and French Cadastral System based on LADM Specifications". 2nd International Workshop on 3D Cadastres.

Pouliot, J., Wang, C., Fuchs, V., Hubert, F., and Bédard, M., (2013). "Experiments with Notaries about the Semiology of 3d Cadastral Models:. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 1 (2).

Prandi, F., Soave, M., Devigili, F., Andreolli, M., & De Amicis, R. (2014). "Services Oriented Smart City Platform Based On 3d City Model Visualization". ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, 1,.

Rahman, A., Hua, T.H. and van Oosterom, P. (2011). "Embedding 3D into Multipurpose Cadaster", FIG working week, Marakech.

Rajabifard, A. and Williamson, I.P. (2001). "Spatial Data Infrastructures: Concept, SDI Hierarchy and Future Directions", Proceedings of GEOMATICS'80 Conference, Tehran, Iran.

Rajabifard A. (2014). "3D Cadastres and Beyond". 4th international Workshop on 3D Cadastres. Dubai, United Arab Emirates.

Rajabifard, A., I. Williamson, and Binns, A. (2006). "Marine administration research activities within Asia and Pacific Region– Towards a seamless land-sea interface". FIG, Administering Marine Spaces: International Issues, Publication No. 36.

Rajabifard, A., Kalantari, M., Williamson, I. (2012). "Land and property information in3D". FIG Working Week 2012. Rome, Italy.

Rahibulsadri, R., A. H. Omar, A. Abdullah, W. M. Aizzat, W. Azhar, H. Jamil, T. C. Hua, C. K. Lim and T. A. Bah (2014). "Determination of Tidal Datum for Delineation of Littoral Zone for Marine Cadastre in Malaysia". Lecture Notes in Geoinformation and Cartography 2014.

Robertson, B., Benwell, G. and Hoogsteden, C. (1999). "The marine resource: Administration infrastructure requirements", UN-FIG Conference on Land Tenure and Cadastral Infrastructures for Sustainable Development, Melbourne, Australia.

Rokos, D. [2001]. "Conceptual modeling of real property objects for the Hellenic Cadastre". In: Proceedings of the International Workshop "3D Cadastres", Registration of properties in strata, Delft, The Netherlands.

Sagris V., Wojda P., Milenov P. and Devos W. [2013]. "The harmonised data model for assessing Land Parcel Identification Systems compliance with requirements of direct aid and agri-environmental schemes of the CAP" In: Journal of Environmental Management, 118.

Salat, S. and Bourdic, L. (2012). "Urban complexity, efficiency and resilience". In" Z. Moran (ed.), Energy efficiency - a bridge to low carbon economy (pp.25-44).

Sandberg, H. [2001]. "Three-dimensional division and registration of title to land: Legal aspects". In: Proceedings of the International Workshop on 3D Cadastres , 2001, Delft. The Netherlands.

Sanecki, J., Klewski, A., Beczkowski, K., Pokonieczny, K., Stępień, G. [2013]. "The Usage of DEM to Create 3D Cadastre", Scientific Journals: Maritime University of Szczecin / Zeszyty N; 2013, 105 (33).

Scarponcini, P. [2013]. "InfraGML Proposal" OGC Land and Infrastructure DWG/SWG at: https://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCgQFjAB&url=https%3A%2F%2Fportal.opengeospatial.org%2Ffiles%2F%3Fartifact_id%3D56299&ei=SsUKVfCb0sraPeTygaAE&usg=AFQjCNH7b_53f6eYBsBGPvdMWWKejUHv0A&bvm=bv.88528373,d.ZWU

Shoshani, U., Benhamu, M., Goshen, E., Denekamp S. and Bar, R. [2004]. "Registration of Cadastral Spatial Rights in Israel – A Research and Development Project". FIG Working Week 2004 Athens, Greece.

Shojaei, D., Kalantari, M., Bishop, I.D., Rajabifard, A., Aien, A., [2013]. "Visualization requirements for 3D cadastral systems". In: Computers, Environment and Urban Systems.

Simpson, S. R. (1976)." Land Law and Registration". Cambridge University Press.

Soil Survey Staff. [1999]. "Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys", Natural Resources Conservation Service, U. S. Department of Agriculture Handbook 436.

Soon, K. H. (2010). "Ontological Foundations of Geographical Data". In: Warf, B. (Ed.). *Encyclopedia of Geography*: 4. SAGE Publications.

Soon, K. H. [2013]. "Representing roles in formalizing domain ontology for land administration". In: Proceedings 5th Land Administration Model. Kuala Lumpur, Malaysia.

Stadler, A., Kolbe, T.H., [2007]. "Spatio-semantic coherence in the integration of 3D". In: 5th International ISPRS Symposium on Spatial Data Quality ISSDQ 2007, Enschede, The Netherlands.

Steudler, D., [2004]. "Swiss Cadastral Core Data Model – Experiences of the last 15 years". Joint 'FIG Commission 7' and 'COST Action G9' Workshop on Standardization in the Cadastral Domain Bamberg, Germany,

Stoter, J.E. (2004) [Ph.D. Thesis]. "3D Cadastre". Delft University of Technology, Delft, the Netherlands.

Stoter, J. E., Ploeger, H. D. (2002). "Multiple Use of Space: Current Practice of Registration and Development of a 3D Cadastre". In: E.M. Fendel, K. Jones, R. Laurini et al (Eds.), Proceedings of UDMS 2002, 23rd Urban Data Management Symposium. Prague, Czech Republic.

Stoter, J.E., Van Oosterom, P.J.M. (2005). "Technological aspects of a full 3D cadastral registration". In: International Journal of Geographical Information Science IJGIS.

Stoter, J.E., Van Oosterom, P.J.M. (2006). "3D Cadastre in an International Context: Covering legal, organizational, and technological aspects", CRC Press.

Stoter, J., van Oosterom, P. and Ploeger, H. [2012]. "The phased 3D Cadastre implementation in the Netherlands". 3rd International Workshop on 3D Cadastres: Developments and Practices, Shenzhen, China.

Stoter, J. and Zevenbergen, J. [2001]. "Changes in the definition of a property: A consideration for a 3D Cadastral registration system" FIG Working Week 2001. Seoul, Korea. at: https://www.fig.net/pub/proceedings/korea/full-papers/session27/stoter-zevenbergen.htm

Stoter, J.E. and S. Zlatanova [2003]. "Visualising and editing of 3D objects organised in a DBMS". EUROSDR workshop: Rendering and visualisation, January 2003, Enschede, The Netherlands

Strain, L., Rajabifard, A. and Williamson, I.P. (2006). "Spatial Data Infrastructure and Marine Administration", Marine Policy, 30.

Sutherland, M. D. (2005) [Ph.D. Thesis]. "Marine Boundaries and Good Governance of Marine Spaces", Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, Canada.

Sutherland, M. and Nichols, S. (2009). "Developing a Prototype Marine Cadastre for Chedabucto Bay, Nova Scotia", In: Proceedings of the FIG Working Week, Eilat, Israel.

Stubkjær [2000]. "Real Estate and the ontology of multidisciplinary, e.g. Cadastral Studies". In: Geographical Domain and Geographical Information Systems, EuroConference on Ontology and Epistemology for Spatial Data Standards, France, 2000

Tan, L.C. and Looi, K.S. (2013). "Towards a Malaysian Multipurpose 3D Cadastre based on the Land Administration Domain Model (LADM) – An Empirical Study". In: Proceedings of the 5th FIG Land Administration Domain Model Workshop, Kuala Lumpur, Malaysia.

Thompson R. (2013). "Progressive Development of a Digital Cadastral Data Base". In: Proceedings of the 5th FIG Land Administration Domain Model Workshop, Kuala Lumpur, Malaysia.

Thompson R. and van Oosterom, P. (2010). "Integrated Representation of (Potentially Unbounded) 2D and 3D Spatial Objects for Rigorously Correct Query and Manipulation". 5th Intenational 3D GeoInfo Conference, Berlin, Germany.

Tsiliakou, E., Labropoulos, T. andDimopoulou, E. (2013). "Transforming 2d Cadastral Data Into a Dynamic Smart 3d Model". ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,1 (2).

Tsiliakou, E. and Dimopoulou, E., (2011). "Adjusting the 2D Hellenic Cadastre to the Complex 3D World - Possibilities and Constraints". In: Proceedings of the 2nd International Workshop on 3D Cadastres. TU Delft, The Netherlands.

Tzeferis, G. P., Kvalopoulos, C., Komnitsas, K. [2012]. "Production data and sustainable development indicators [SDIs] for the Greek Nining/Metallurgical Industry in the period 2007-2011".

United Nations Economic Commission for Europe (UNECE) (1996). "Land Administration Guidelines". Meeting of Officials on Land Administration, United Nations Economic Commission of Europe. ECE/HBP/96.

UN-Habitat, (2003). "Handbook on best practices, security of tenure and access to land". Nairobi, Kenya, United Nations Human Settlements Programme. Unedited version.

United Nations Economic Commission for Europe (UNECE) (2005). "Land Administration in The

UNECE Region: Development Trends and Main Principles. United Nations Economic Commission for Europe. ECE/HBP/140.

UN-Habitat, (2008). "Secure land rights for all". Nairobi, Kenya.

Valta, K., Komnitsa, K., Grossiu-Valta, M. [2007]. "Sustainable development indicators for the Greek industrial minerals sector". In: Proceedings, SDIMI 2007.

Van Loenen B., Kok C. B. [2004]. "Spatial Data Infrastructure and policy development in Europe and the united States". DUP Science.

Van der Molen, P. [2003]. "Institutional aspects of 3D cadastres". Computers Environment and Urban Systems, 27, (4).

van Oosterom [2012]. 3rd International FIG Workshop on 3D Cadastres – Developments and practices. Shenzen. China.

Van Oosterom, P.J.M, Lemmen, C.H.J, Uitermark H., Boekelo G., and Verkuijl G., (2011). "Land Administration Standardization with focus on Surveying and Spatial Representations". In: Proceedings of the ACMS Annual Conference Survey Summit, San Diego.

Van Oosterom, P., Stoter, J. Ploeger, H., Thompson, R., Karki, S. (2011). "World-wide Inventory of the Status of 3D Cadastres in 2010 and Expectations for 2014", FIG Working Week, Morocco.

Van Oosterom, P.J.M and Stoter, J. [2012]. "Principles of 5D modeling". In: Geospatial World weekly 29 October 2012. At: http://geospatialworld.net/Paper/Technology/ArticleView.aspx?aid=30344

Van Oosterom, P.J.M. [2013]. "Research and Development in 3D Cadastres". Computers Environment and Urban Systems, 40.

Van Oosterom, P., Stoter, J., Ploeger, H., Thompson, R. and Karki, S. [2011]. "World-wide inventory of the status of 3D Cadastres in 2010 and expectations for 2014". In:

Proceedings of the 2011 FIG Working Week, Bridging the Gap between Cultures , Marrakech, Morocco.
Van Oosterom, P. [2014]. "Survey of Israel Three-Dimensional Cadastre and the ISO 19152 – The Land Administration Domain Model – Report 2 (updated version). TUDelft
Vandysheva, N., Tikhonov, V., Van Oosterom, P., Stoter, J., Ploeger, H., Wouters, R., Penkov, V. (2011). "3D Cadastre Modelling in Russia". Proceedings FIG Working Week 2011, Marrakech.
Vitikainen, A. and Hiironen, J. [2012]. "Development Scenarios of the 3D Cadastral System in Finland". FIG Working Week, Knowing To Manage The Territory, Protect The Environment, Evaluate The Cultural Heritage.
Vučić, N., Roić, M. and Kapović, Z. [2011]. "Current Situation and Perspective of 3D Cadastre in Croatia". 2nd International Workshop on 3D Cadastre. Delft, the Netherlands
Wang, C., Pouliot, J., and Hubert, F. (2012). "Visualization principles in 3D cadastre: A first assessment of visual variables". In: Proceedings 3rd international workshop on 3D cadastres. Shenzhen, China.
Williamson, I.P., Enemark, S., Wallace, J. and Rajabifard, A. (2010). "Land Administration for Sustainable Development", Published by ESRI Press Academic, Redlands, California, 2010, ISBN 978-1-58948-041- 4.
Williamson, I.P., Leach, J. and Rajabifard, A. (2001). "Position Paper for Marine Cadastres". 7th Meeting of the Permanent Committee on GIS Infrastructure for Asia and Pacific (PCGIAP), Tsukuba Japan. At: http://www.sli.unimelb.edu.au/maritime/
W3C OWL Working Group (2012). OWL 2 Web Ontology Language: Document Overview (Second Edition). Retrieved July 10, 2013, from http://www.w3.org/TR/owl2-overview/.
Ying, S., Guo, R., Li, L., Van Oosterom, P., Ledoux H. and Stoter, J. [2011]. "Design and Development of a 3D Cadastral System Prototype based on the LADM and 3D Topology". 2nd International Workshop on 3D Cadastres, Delft, the Netherlands.
Zedlitz, J., Jörke, J. and Luttenberger, N. (2012). "From UML to OWL 2". Knowledge Technology, Springer Berlin Heidelberg
Zentelis P., (2011). "Concerning Land Matters and Cadastre". Papasotiriou, ISBN: 978-960-491-014-4.
Zentelis, P. and Dimopoulou, E. (2001). "The Hellenic Cadastre in Progress: a Preliminary Evaluation, first Special Issue on Cadastral Systems". International Journal on Computers, Environment and Urban Systems, 25 (4-5).
Zulkifli, N.A., Abdul Rahman, A., Jamil, H., Teng C.H., Tan L.C., Looi K.S., Chan K.L., and van Oosterom, P. (2014a). "Towards Malaysian LADM Country Profile for 2D and 3D Cadastral Registration System". FIG Congress 2014 – Engaging the Challenges, Engaging the Relevance, Kuala Lumpur, Malaysia.
Zulkifli, N.A., Abdul Rahman, A., Jamil, H., Teng C.H., Tan L.C., Looi K.S., Chan K.L., and van Oosterom, P. (2014b). "Development of a prototype for the assessment of the Malaysian LADM Country Profile". In: Proceedings of FIG Congress 2014, Kuala Lumpur, Malaysia.
Zlatanova, S., (2002). "The future of 3D geo-information". Jubilee scientific conference on the occasion of the 60th anniversary of the University of Architecture Civil Engineering and Geodesy, Vol. 8, Geodesy, Transportation Engineering, Geotechniques, Mathematics and Physics. Sofia, Bulgaria.
Zlatanova, S. [2006]. "3D geometries in DBMS". Innovations in 3D GeoInformation Systems, LNG&C. Springer, Heidelberg, Germany.
Zlatanova, S., Prosperi, D. [2006]. "Large-scale 3D Data Integration: Challenges and Opportunities". Taylor and Francis, UK.
Zlatanova, S., Lee, J., [2008]. "A 3D data model and topological analyses for emergency response in urban areas". In: Geospatial Information Technology for Emergency Response.
Zlatanova, S., Stoter, J., and Isikdag, U. (2012). "Standards for exchange and storage of 3D information: Challenges and opportunities for emergency response". In: Proceedings of the Fourth International Conference on Cartography and GIS, Albena, Bulgaria.
Αθανασίου, Α., [2014]. "Σχεδιασμός μοντέλου για τη διαχείριση του Ελληνικού θαλάσιου χώρου με νάση διεθνή πρότυπα". Διπλωματική Εργασία, ΣΑΤΜ, ΕΜΠ, Αθήνα.
Γόγολου, Χ.. [2013]. "Σχεδιασμός μοντέλου για το αρχαιολογικό κτημ τολόγιο με βάση διεθνή πρότυπα". Διπλωματική Εργασία, ΣΑΤΜ, ΕΜΠ, Αθήνα.
Ζεντέλης, Π., (2011a). "Περί Κτημάτων λόγος και Κτηματολόγιο", Τόμος Α Εκδόσεις Παπασωτηρίου, Αθήνα 2011.

Ζεντέλης, Π., (2011b). "Περί Κτημάτων λόγος και Κτηματολόγιο", Τόμος Β, Εκδόσεις Παπασωτηρίου, Αθήνα 2011.

Καλογιάννη, Ε. (2012). "Σχεδιασμός μοντέλου για τη διαχείριση της Δημόσιας Περιουσίας στην Ελλάδα". Διπλωματική Εργασία, ΣΑΤΜ, ΕΜΠ, Αθήνα.

Τσιλιάκου, Ε. (2014) «Κανονιστική μοντελοποίηση στο 3D Κτηματολόγιο – Εφαρμογή στην Πολυτεχνειούπολη Ζωγράφου". Διπλωματική Εργασία, ΣΑΤΜ, ΕΜΠ, Αθήνα.

Ψωμαδάκη, Σ. (2014). "Διερεύνηση των δυνατοτήτων εναρμόνισης του Εθνικού Κτηματολογίου με Διεθνή Πρότυπα". Διπλωματική Εργασία, ΣΑΤΜ, ΕΜΠ, Αθήνα.

http://archeocadastre.culture.gr

http://www.beforeyoubuyacondo.com/condovsstrata.html].

www.citygmlwiki.org

http://www.csdila.unimelb.edu.au/sis/Land_Theories/SDI_Hierarchy.html

http://geniepad.com/posts/204-what-is-the-difference-between-condo-strata-hoa-and-co-op-associations].

http://www.ktimatologio.gr/sites/en/aboutus/Pages/qoQhyNCvtozm6ajS_EN.aspx

http://www.opengeospatial.org/ogc/faq/process

[http://www.opengeospatial.org/ogc/members;http://www.iso.org/iso/home/about.htm]

http://inspire.ec.europa.eu/index.cfm/pageid/42/list/6/id/16506

www.gltn.net

http://www.geo-bim.org/europe/speaker.htm

http://www.ifcwiki.org/index.php/Basic_Informations

http://www.landxml.org

http://www.interlis.ch/interlis1/description_e.php

http://www.opengeospatial.org/ogc/members;

http://www.opengeospatial.org/blog/2098, http://geospatial.blogs.com/geospatial/2013/12/a-proposal-to-replace-landxml-with-infragml.html].

http://www.iso.org/iso/home/about.htm].

http://www.csdila.unimelb.edu.au/sis/Land_Theories/SDI_Hierarchy.html

http://inspire.ec.europa.eu

http://www.visitgreece.gr/en/nature

http://wiki.tudelft.nl/pub/Research/ISO19152/ImplementationMaterial/LADMOntology.owl.

http://www.beforeyoubuyacondo.com/condovsstrata.html

http://geniepad.com/posts/204-what-is-the-difference-between-condo-strata-hoa-and-co-op-associations

Appendixes

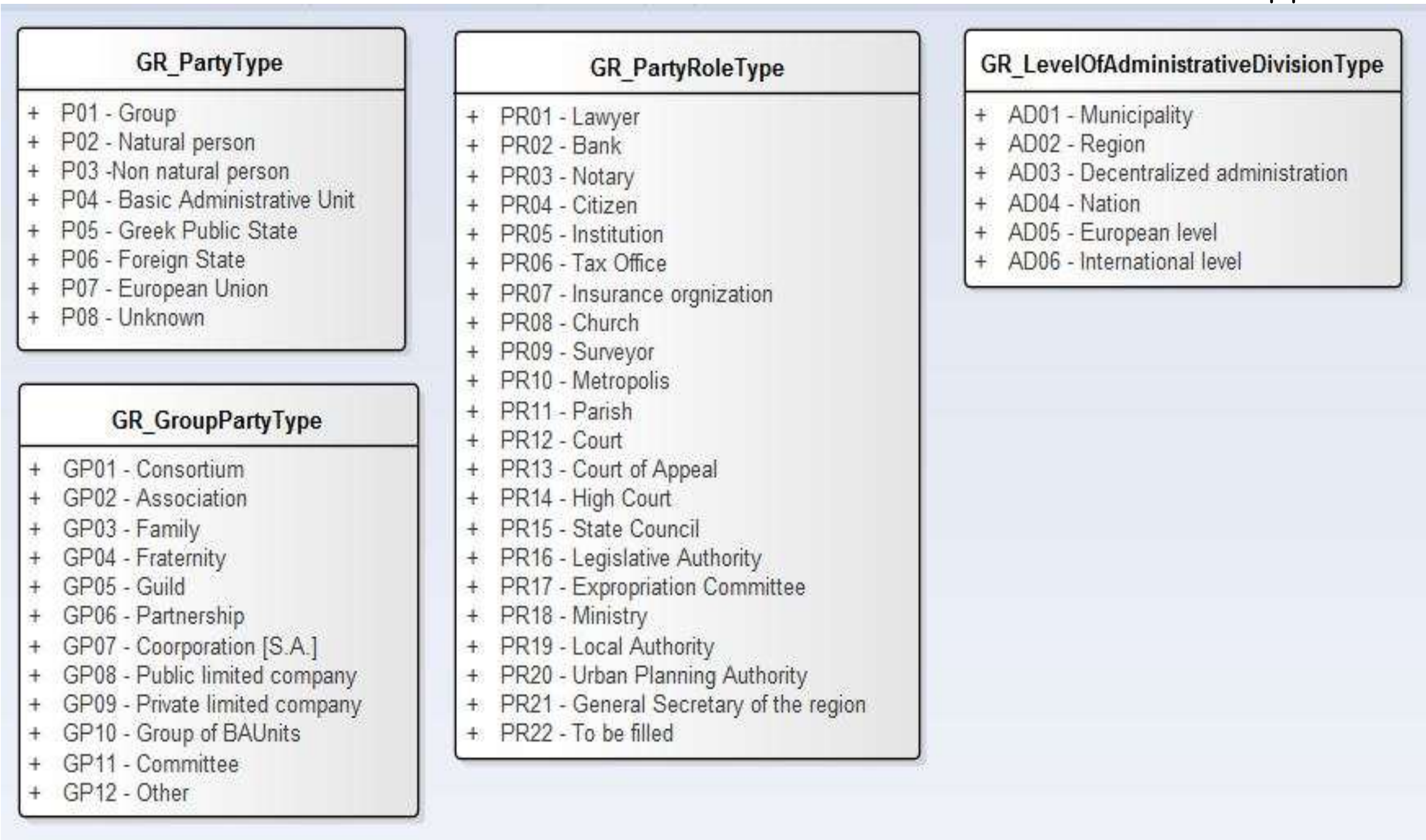
Appendix A – Descriptive database of the HC

Appendix B – Code lists of the non-spatial part (Party Package) of the proposed model

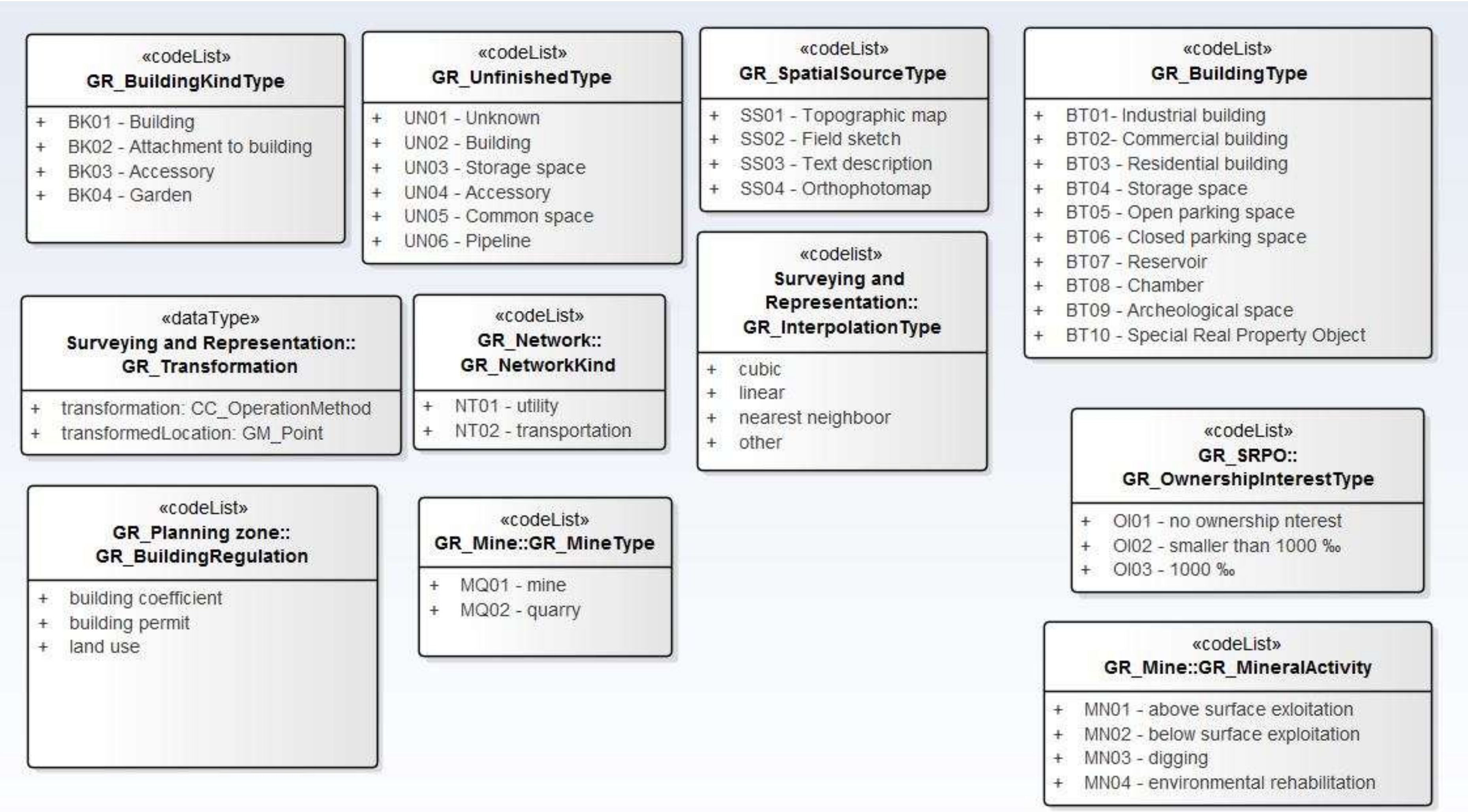
Appendix C – Code lists of the spatial part of the proposed model

Appendix A

Appendix B


GR_PartyType
+ P01 - Group
+ P02 - Natural person
+ P03 -Non natural person
+ P04 - Basic Administrative Unit
+ P05 - Greek Public State
+ P06 - Foreign State
+ P07 - European Union
+ P08 - Unknown
GR_GroupPartyType
+ GP01 - Consortium
+ GP02 - Association
+ GP03 - Family
+ GP04 - Fraternity
+ GP05 - Guild
+ GP06 - Partnership
+ GP07 - Coorporation [S.A.]
+ GP08 - Public limited company
+ GP09 - Private limited company
+ GP10 - Group of BAUnits
+ GP11 - Committee
+ GP12 - Other
GR_PartyRoleType
+ PR01 - Lawyer
+ PR02 - Bank
+ PR03 - Notary
+ PR04 - Citizen
+ PR05 - Institution
+ PR06 - Tax Office
+ PR07 - Insurance orgnization
+ PR08 - Church
+ PR09 - Surveyor
+ PR10 - Metropolis
+ PR11 - Parish
+ PR12 - Court
+ PR13 - Court of Appeal
+ PR14 - High Court
+ PR15 - State Council
+ PR16 - Legislative Authority
+ PR17 - Expropriation Committee
+ PR18 - Ministry
+ PR19 - Local Authority
+ PR20 - Urban Planning Authority
+ PR21 - General Secretary of the region
+ PR22 - To be filled
GR_LevelOfAdministrativeDivisionType
+ AD01 - Municipality
+ AD02 - Region
+ AD03 - Decentralized administration
+ AD04 - Nation
+ AD05 - European level
+ AD06 - International level

Appendix C


«codeList»
GR_BuildingKindType
+ BK01 - Building
+ BK02 - Attachment to building
+ BK03 - Accessory
+ BK04 - Garden
«codeList»
GR_UnfinishedType
+ UN01 - Unknown
+ UN02 - Building
+ UN03 - Storage space
+ UN04 - Accessory
+ UN05 - Common space
+ UN06 - Pipeline
«codeList»
GR_SpatialSourceType
+ SS01 - Topographic map
+ SS02 - Field sketch
+ SS03 - Text description
+ SS04 - Orthophotomap
«codeList»
GR_BuildingType
+ BT01- Industrial building
+ BT02- Commercial building
+ BT03 - Residential building
+ BT04 - Storage space
+ BT05 - Open parking space
+ BT06 - Closed parking space
+ BT07 - Reservoir
+ BT08 - Chamber
+ BT09 - Archeological space
+ BT10 - Special Real Property Object
«dataType»
Surveying and Representation::
GR_Transformation
+ transformation: CC_OperationMethod
+ transformedLocation: GM_Point
«codeList»
GR_Network::
GR_NetworkKind
+ NT01 - utility
+ NT02 - transportation
«codelist»
Surveying and
Representation::
GR_InterpolationType
+ cubic
+ linear
+ nearest neighboor
+ other
«codeList»
GR_SRPO::
GR_OwnershipInterestType
+ OI01 - no ownership nterest
+ OI02 - smaller than 1000 ‰
+ OI03 - 1000 ‰
«codeList»
GR_Planning zone::
GR_BuildingRegulation
+ building coefficient
+ building permit
+ land use
«codeList»
GR_Mine::GR_MineType
+ MQ01 - mine
+ MQ02 - quarry
«codeList»
GR_Mine::GR_MineralActivity
+ MN01 - above surface exloitation
+ MN02 - below surface exploitation
+ MN03 - digging
+ MN04 - environmental rehabilitation