Profile Definition for a Standardized Cadastral Model

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SUMMARY

The move towards a standardized cadastral domain model is a challenging endeavour since the model must address an administrative or legal component, as well as a spatial component. The goal of any model is to simplify and provide an abstraction of a complex and diverse world. If the model can be standardized, interfaces between data, users, and systems can provide a mechanism that will allow the physical sharing of cadastral data among many implementations.

While considerable work has been done by a number of agencies to provide local models that define logical cadastral entities, attributes, domains and relationships, the models do not provide guidelines for publicizing the content of a cadastral database in a form that is understandable by stakeholders; some whom may not understand data model semantics but possess knowledge of the cadastral domain. This situation was identified in *Cadastral 2014 – A Vision for a Future Cadastral System* where most land recording systems consist of a land registry component handled by notaries and lawyers and a separate spatial component taken care of by surveyors.

In order to bridge the communication gap, a number of agencies are developing cadastral profiles that detail metadata attribute content and data dictionaries that support the transfer of a cadastral logical model to a physical model.

As outlined by a number of cadastral organizations, like the US Federal Geographic Data Committee, and supported by other organizations that have implement standards such as the International Hydrographic Organization (IHO), a profile is often the first step in a government effort to index cadastral information. These profiles and applicable standards define the metadata elements required to support enhanced data discovery and the development of information access systems.

Through this paper, the authors present criteria which governments might consider in documenting its cadastral profile, as well as the international standardization issues that must be considered in doing so in order to successfully move forward.
Finally, this paper reviews a methodology by which cadastral profiles developed by a number of agencies can be compared identifying their similarities and differences. In addition, the authors introduce collection criteria used to identify individual real world phenomena used to define features objects within a cadastral domain model.

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1. INTRODUCTION

The interest and evolution of cadastral systems follow a cyclic pattern within the global community driven by social, economic and political reforms. Over the last decade there has seen a renewed interest in cadastral systems in response to the pressures of change (Dale, 2000). During this period of time we have seen:

- The emergence of a number of land reform programs, especially in the former Soviet Union, the Balkans and Latin America;

- The growing integration of economies and societies around the world; and

- Increased advancements being made in information technologies (IT), particularly in the fields of communications and data management.

In order to establish an agenda for the evolution of current cadastral systems Commission 7 of FIG reviewed very carefully institutional, economic, social and technologies changes affecting cadastral systems, partly in terms of developing a vision for the future. This vision was present in "Cadastre 2014" (Kaufmann and Steudler, 1998) that formulated six statements for the development of cadastral systems. In summary, the statements are:

1. Cadastre 2014 will show the complete legal situation of land, including public rights and restrictions;

2. The separation between 'maps' and "registers' will be abolished;

3. The cadastral mapping will be dead. Long live modeling;

4. "Paper and pencil" – cadastral will be gone;

5. Cadastre 2014 will be highly privatized. Public and private sectors are working closely together;

6. Cadastre 2014 will be cost recovering.

Overall Cadastre 2014 introduces a number of concepts that should be contemplated, which can be considered as jurisdictional, organizational and structural in nature. However, underlining these concepts is the utilization of technology and technological principals. It is important to realize that technology is not the solution but a set of tools used to assist in the design, deployment and operation of a cadastral system.

2. CADASTRAL DOMAIN MODEL

The complexities of cadastral systems can get bogged down in theoretical discussions. In order to facilitate a more practical discussion a Core Cadastral Domain Model was launched at the FIG Congress in Washington (Oosterom, van, Lemmen, 2002). It was viewed that a simple, generic, standardized data model could encourage and support the flow of information relating land property between different government agencies, and in turn to the public (Lemmen, Oosterom, van, April 2003).

One of the primary elements of presenting the Core Cadastral Domain Model was the use of the ISO standard modeling language UML (Unified Modeling Language). The use of a modeling language is important because it helps a development team visualize, specify, construct, and document the structure and behavior of a system's architecture. By using a modeling language, like UML, members of the development team can unambiguously communicate their decisions to one another (Unified Modeling Language; Booch, Rumbaugh, Jacoboson, 1999).

The basis for UML is the Rational Unified Process, which is a disciplined approach for assigning and managing tasks and responsibilities in a development organization. It captures many of the best practices used in modern software development and presents them in a tailorable form (Kruchten, 2000).

The use of best practices focuses on using commercially proven approaches to software development, when used in combination; address the root causes of software development problems (Chapter 1, Booch, 2000). Though a number of organizations list best practices as part of their software development process the Rational Unified Process identify the following:

1. Development is iterative;

2. Requirements are managed;

3. Use component-based architectures;

4. Visually model software and system architects;

5. Continuously verify software and system architects quality;

6. Control changes.

Since its introduction, the evolution of a Core Cadastral Domain Model appears to have adhered to the best practices of the Rational Unified Process. Since cadastral systems are complex, one of the notable acknowledgements is that the model will most likely be implemented as a distributed set of information systems; component-based architectures. This means that the model recognizes that different organizations have their own responsibilities in data maintenance and supply. This recognition is reflected in its use of colour coding allowing domain experts to focus on their area of interest rather than the whole model (Lemmen, Oosterom, van, April 2003). In draft version 2, the Core Cadastral Domain Model components were presented as:

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- Green: real core;

- Green and yellow: legal/administrative aspects;

- Green and Blue: real estate object specializations;

- Blue, pink and purple: geometric/topological aspects.

However, since the whole model is presented there is a recognition that organizations have to communicate on the basis of standard processes, thus adding value to the entire system (Lemmen, Oosterom, van, April 2003).

The primary focus of the Core Cadastral Domain Model has been on the development of a class diagram using UML. The use of UML will enable database specialists all over the world to understand the direction the working group supporting the standard is heading and be to contribute to the standard (Lemmen, Oosterom, van, April 2003). In essence, the working group is using a standard to develop a standard.

The working group also recognizes that UML also provides support for the implementation of a cadastral system through the use of:

- Behavioral diagrams that model activities, use case, timing, communications, interactions, etc.

- Structural diagrams that encompass classes, objects, packages, deployment, etc.

The challenge for system integrators and consultants is: How do we get domain experts, such as registrars, surveyors, lawyers, etc., who can contribute to the behavior of a cadastral system to contribute to the structural development of the Core Cadastral Domain Model?
One proposed method is to have domain experts contribute to a gap analysis by comparing what they have to what the Core Cadastral Data Model proposes. If the gap analysis is modeled using UML then domain experts will gain an understanding of the UML standard, which in turn may allow them to participate in the development of the Core Cadastral Domain Model, or at least provide some feedback to the database specialists who are contributing to the working group.

3. GAP ANALYSIS

The exercise of doing a gap analysis is not new in establishing and adopting a standard. Two case studies of interest are users wishing to work with the:

- Cadastral Data Content Standard developed by the US Federal Geographic Data Committee (FGDC) that provides a standard for the definition and structure for cadastral data which will facilitate data sharing at all levels of government and the private sector and will protect and enhance the investments in cadastral data at all levels of government and the private sector. The standard is presented as entities and attributes as well as suggested domain values for some attributes. The presentation of the standard is organized as an entity-relationship model (FGDC, 2003).

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- International Hydrographic Organization (IHO) Transfer Standard S-57 that is intended to support the exchange of vector (and later raster and matrix) hydrographic data among producers and users worldwide. The standard is comprised of a theatrical data model, presented as a UML class diagram, on which the standard is based. The standard also describes the data structure and a catalogue of objects (Guy, 1999).

The methodology for doing a gap analysis is best illustrated by the Internet user's guide supporting the FGDC Cadastral Data Content Standard (Section 5, Bureau of Land Management, 2002). In the user's guide a gap analysis is referred to as a "Crosswalk" exercise. The objective is to determine which parts of an established database correspond to the Standard by comparing the standard logical model with entities in an established database.

The purpose of a crosswalk is to express data definitions and relationships on terms of the Standard. By doing this, domain experts would be able to recognize the similarities and differences thus facilitating discussions about the Standard.

Though the user's guide focuses on comparing entities and relationships within an existing database to the Standard the methodology can be expanded to non-digital environments.

For example, within the Core Cadastral Domain Model, version 3, there is a class "SurveyDocument" with attributes "Number" and "Measurements" (Oosterom, van, Grise, Lemmen, September 2003). Many cadastral offices still maintain survey documents in paper form. On the survey document there are reference numbers and measurements but there are also dates. People working with survey documents are domain experts in their own right and can contribute to the discussion by comparing their circumstances with the Model. In this example, which is easier to illustrate using attributes rather than classes, should date be part of the standard and if so what date; date of submission, registered date, etc. Inversely, should the date of a survey document be left as an extension to the Model invoked at the discretion of the organization?

In addition, when viewing the Model people can see that the "SurveyDocument" is associated to a "SurveyPoint", which in turn is associated to a "ParcelBoundary". This may or may not make logical sense to an organization but they can at least start understanding the Model and, if they wish, contribute to the discussion, even if they are not a database specialist.
A second example can be illustrated by doing a "crosswalk" comparing the FGDC Cadastral Data Content Standard with the Core Cadastral Domain Model. In doing so we can see that the Standard has identified entities such as "Coordinate Reference" and "Public Agency" that are not included in version 3 of the Model.

In the case of the IHO transfer standard, S-57, we are dealing with a much more mature model that is actively being used in the International community. Though the model is well established, it has been observed that some agencies produce specialized products and wish to extend the standard. More often this involves adding object classes and attributes. A gap analysis in this case identifies what organizations can inherit from the standard. More importantly the standard clearly defines a set of conventions used to define object classes and attributes (IHO-A, 2000 and IHO-B, 2000).

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In performing a gap analysis the authors have found that the conventions used in the IHO transfer standard, S-57, assist in clarifying the definition of classes and associated attributes. By using UML to present the results there is an improvement when comparing contributions from domain experts with the Core Cadastral Domain Model.

4. CADASTRAL FEATURE CATALOGUE

The cadastral feature catalogue is the data schema for defining the content of a cadastre system that can be in either digital and/or analogue form. Its primary function is to provide a means of describing real world entities. That is entities, which actually exist (either physically such as a control monument or legally such as a land parcel) in the real world.
The cadastral feature catalogue is based on the theoretical model often described by the agency supporting a cadastre. The catalogue is composed of:

- A profile that is a physical representation of the theoretical model; and

- A data dictionary describing attributes supporting classes defined in the profile.

The theoretical model assumes that real world entities can be categorized into a finite number of packages or aspects. In version 3 of the Core Cadastral Domain Model these are defined as (Oosterom, van, Grise, Lemmen, September 2003):

- Specialized classes of a "RealEstateObject", as an abstract class;

- Surveying classes;

- Geometry and Topology classes;

- Legal and administrative classes.

It is the objective to categorize an existing cadastre using the aspects of the Core Cadastral Domain Model in order to define a clearer definition of classes when doing a gap analysis.
An instance of class, referred to as an object, (that is one specific parcel boundary or legal document or person) can be more precisely described by assigning to it a number of attributes and then specifying values for those attributes. A particular class is encoded by specifying the appropriate object class, attributes and attribute values.

The objective of the cadastral feature catalogue is to develop a description of each object class including a definition, a list of allowable attributes, etc.

The cadastral feature catalogue does not mandate the use of any attributes. However, for each instance of an object, a particular attribute may only be used once. In general terms it is up to the encoder to select from the appropriate list the attributes that are relevant to a particular object instance.

Attributes will be presented following the discussion on classes.
Each object class within the cadastral feature catalogue is specified in a standardized way, under the following headings:

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- **Class** – A class name such as "ParcelBoundary". It should be noted that UML does not allow spaces so that some abstraction may be applied. If an abstraction is used clarification can be noted in the description of the class;

- **Acronym** – In order to cross-reference a class to a database schema acronyms are often used. In order to accommodate most database systems a six-character code for the class is used;

- **Code** – This is just an integer code to be used to index the object class;

- **Description** - Where possible each class should carry a definition. The objective is to clarify the class for other users;

- **References** – Used to identify the source of the class and/or meaning of the definition;

- **Remarks** – Used to provide additional comments and notes for the class;

- **Data Type** – This presently describes what spatial object type(s) is assigned to a class such as line, area, point, etc. Discussions are proceeding to define other types identified in the Core Cadastral Domain Model such as instrument, right, person, etc.

- **Constraint** – For every attribute that is supporting a class an organization may consider whether it is mandatory (M) and/or read-only (R).

For example, using the FDGC Cadastral Data Content Standard for the National Spatial Data Infrastructure, Version 1.3, the following standard would be used to define an object class for a Parcel.

Column	Description
Class	Parcel
Acronym *	CDPRCL
Data Type *	Area
Aspect *	RealEstateObject
Code *	44
Attributes	CDPID$ (M), CDPART (M), CDPARN, CDPRL1, CDPIDA
Definition	A Parcel is a single cadastral unit, which is the spatial extent of the past, present, and future rights and interests in real property.
References	FGDC Cadastral Data Content Standard – Version 1.3
Remarks *	Additional attributes may be added to support presentation of the object class and describe the administrative characteristics.

Table 1 - Object Description for a FGDC Parcel

* Denotes that this column is unique to the cadastral feature catalogue and not part of the FGDC description.

The attributes used in this example are:

- CDPID$ - ParcelIdentifier

- CDPART – ParcelType

- CDPARN – ParcelName

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- CDPRL1 – ParcelLabel

- CDPIDA – ParcelIdentifierAssigner

Each attribute is specified in a standardized way, under the following headings:

- **Attribute** - Attribute name such as "Survey Date". Like classes, it should be noted that UML does not allow spaces so that some abstraction may be applied. If an abstraction is used clarification can be noted in the description of the attribute;

- **Acronym** – Again like classes in order to cross-reference an attribute to a database schema acronyms are often used. In order to accommodate most database systems a six-character code for the class is used;

- **Code** - This is an integer code to be used to index the object class;

- **Attribute Type** – The following types can be assigned to an attribute:

  o **Enumerated** - The expected input is a number selected from a list of pre-defined attribute values. Exactly one value must be chosen. The number is associated to a code list;

  For example, for a digital data source attribute 0 - regular, 1 – digitised enhanced topographic base, 2 – property map, etc.

  o **List** - The expected input is a list where one or more pre-defined attribute values can be selected;

  o **Float** - The expected input is a floating-point numeric value with defined range, resolution, units and format;

  o **Integer** - The expected input is an integer numeric value with defined range, units and format;

  o **Coded String** - The expected input is a string of ASCII characters in a predefined format. The information is encoded according to defined coding systems e.g.: the nationality will be encoded by a two character field specified by ISO 3166 'Codes for the Representation of Names of Countries', e.g. Canada => 'CA';

  o **Character** - The expected input is a free-format alphanumeric string;

  o **Date** – Used to define an instant in time;

  o **Multimedia** – The expected input is a directory path or URL pointing to a multimedia file;

  o **Raster** – The expected input is to a directory path or URL pointing to an image file;

  o **Text** – The expected input is to a directory path or URL pointing to text;

  o **Unknown** – In certain circumstances the attribute has been identified but a specific type classification is still being defined. In order to continue

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developing a cadastral feature catalogue the user can flag this as "UNKNOWN" and edit the type later;

   o **Unsigned Character** – This is a blob or binary record. The standard format is to indicate the number of bytes at the beginning of the record followed by the binary record.

- **Description** - Where possible each object class should carry a definition. The objective is to clarify the attribute for other users;

- **References** – Used to identify the source of the attribute and/or description;

- **Remarks**- Used to provide additional comments and notes for the class;

- **Minimum Value** - The minimum value for the expected input is indicated for float, integer and/or date;

- **Maximum Value** - The maximum value for the expected input is indicated for float, integer and/or date;

- **Indication** - For coded string type attributes (S) it indicates the construction of the string. For integer (I) and floating point (F) type attributes it indicates the units and resolution of the input.

- **Example** - an example of coded input.

Following the previous example, using the FDGC Cadastral Data Content Standard for the National Spatial Data Infrastructure, Version 1.3, the following standard would be used to define attributes for a Parcel.

Column	Description
Attribute	Parcel ID
Acronym *	CDPID$
Attribute Type *	Integer
Code *	32
Description	The Parcel ID is the primary key, which identifies each record or occurrence in the Parcel entity. This is normally the system assigned number that manages record relationships internal to systems.
References*	FGDC – Version 1.3
Minimum Value*	1
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 2 - Attribute Example for Parcel ID

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Column	Description
Attribute	Parcel ID Assigner
Acronym *	CDPIDA
Attribute Type *	Enumerated
Code *	33
Description	This is a designation for the agency, organization or jurisdiction that assigns and maintains the primary key. If possible, this designation should follow known naming standards, such as the Federal Information Processing System (FIPS) codes for jurisdictions. 0 – Unknown 1 – State Agency
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 3 - Attribute Example for Parcel ID Assigner

Column	Description
Attribute	Parcel Type
Acronym *	CDPART
Attribute Type *	List
Code *	34
Description	Parcel Type describes the function, purpose, resource or collective purpose for a parcel. The Parcel Type applies to the entire parcel. The parcel type is categorization that can be useful for display or management. The domains of values are listed as suggested content. The content of this attribute is not standardized. 0 – Unknown 1 – Taxable 2 - Right of Way 3 - General Common Element 4 – Water 5 - Ownership
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 4 - Attribute Example for Parcel Type

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Column	Description
Attribute	Parcel Name
Acronym *	CDPARN
Attribute Type *	Character
Code *	35
Description	The Parcel Name is an identifying name or number for a Parcel. It may also be a project number or any other label for a parcel such as park name.
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 5 - Attribute Example for Parcel Name

Column	Description
Attribute	Parcel Labels
Acronym *	CDPAL1
Attribute Type *	Character
Code *	36
Description	Formerly Parcel Local Label. Local governments or other organizations may have a method or system for identifying and then applying a number for parcels. These numbers are often used for local administrative purposes. These attributes, and there may be many, refer to parcel identification systems that are sometimes called natural keys or other user recognizable identifiers. The form and content and rules for parcel labels should be included with the metadata. Parcel ID is a common name for this label in local governments.
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	CDPRL1 is considered the primary parcel identifier. If additional labels are required than extend the attribute list by adding CDPRL2, CDPRL3, etc.

Table 6 - Attribute Example for Parcel Labels

* Denotes that this column is unique to the cadastral feature catalogue and is not part of the FGDC description.

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5. MODELING THE CADASTRAL FEATURE CATALOGUE

The use of UML to assist in doing the gap analysis provides a number of advantages such as:

- The domain experts have a visual presentation of their existing "model", which is much better than leafing through a document;

- UML is a standardized process that helps remove ambiguities;

- UML lends itself towards an iterative process that can assist organization to compile to a standard;

- A number of UML modeling tools allow multi-models to coexist allowing existing models to inherit properties of a standard. (In order to place this paper in the proper context the authors of this paper use Enterprise Architect version 4.1 developed by Sparx Systems, which supports UML 2.0).

When setting up a UML model for a cadastral feature catalogue there is need to clarify some terminology with regards to "attribute". Within a class UML provides the ability to define attributes for that class. The cadastral feature catalogue data dictionary is also comprised of "attributes" supporting the classes defined in the cadastral feature catalogue profile. Within this document the data dictionary is comprised of "attribute classes".

A representation of a cadastral feature catalogue class is presented in Figure 1, which illustrates a SurveyPoint class generalized by the attribute class SurveyPointCatagorization.
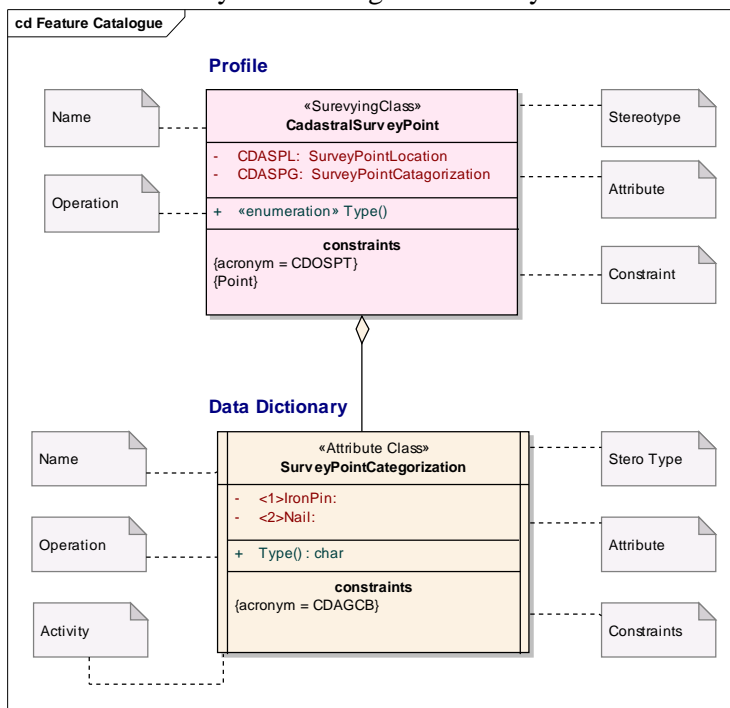

Figure 1 - Cadastral Feature Catalogue Class and Attribute Class

The following section describes the UML properties presented with the cadastral feature catalogue classes:

- **Stereotype** – The stereotypes define the "packages" or aspects defined by the Core Cadastral Domain Model (Lemmen, Oosterom, van, April 2003) plus the addition of Attribute Class;

- **Name** – This defines the name of the class. (Note that UML convention does not support spaces.)

- **Attribute** – An attribute is defined by "name" and "type".

  In the case of a class grouped as an aspect the attribute field is populated with attribute classes. In this case the "name" is the acronym of the attribute class and the "type" is the attribute type. In addition the name can have an extension of mandatory (M) and/or read-only (R).

  In the case of an attribute class attributes can be considered code lists that are general associated with attributes types such as enumeration or list.
  The notation to the right of the attribute defines its "scope", such as private (-), public (+), protected (#) or package (~).

- **Operation** – This field is only used for attribute classes. It is defined by "name" and "returntype" for database definitions like integer, float, character, etc. or "stereotype" for the remaining attribute types like enumeration and list.

  In order to identify the operation as an attribute type the name "Type" is constantly used.

- **Constraints** – This field defines conditions that the class can exist. General one condition is that the class must have an acronym. Though UML tools support this option as an alias, having the acronym as a constraint allows for visual presentation.

  In the case of a cadastral feature catalogue profile class a constraint can also be a data type, such as a line, area, instrument, etc.

- **Activity** – This provides a visual presentation on the status of a class. A double line to the left and right indicate the class is active while a single line indicates it is inactive.

Based on the UML modeling tool being used a number of properties can be defined with the class such as descriptions, references, notes, status, phase, version, etc.

5. 1 Example of Gap Analysis

In order to illustrate how UML can assist in a gap analysis a small example is illustrated in Figure 3. The example uses a portion of the Core Cadastral Domain Model version 3 (Oosterom, van, Grise, Lemmen, September 2003) and the FGDC Cadastral Data Content Standard version 3.1 (FGDC, 2003) modeled using UML. A small portion of both models was used to as an example in order to illustrate the objectives of a gap analysis. The focus of the example is on the class "Parcel".

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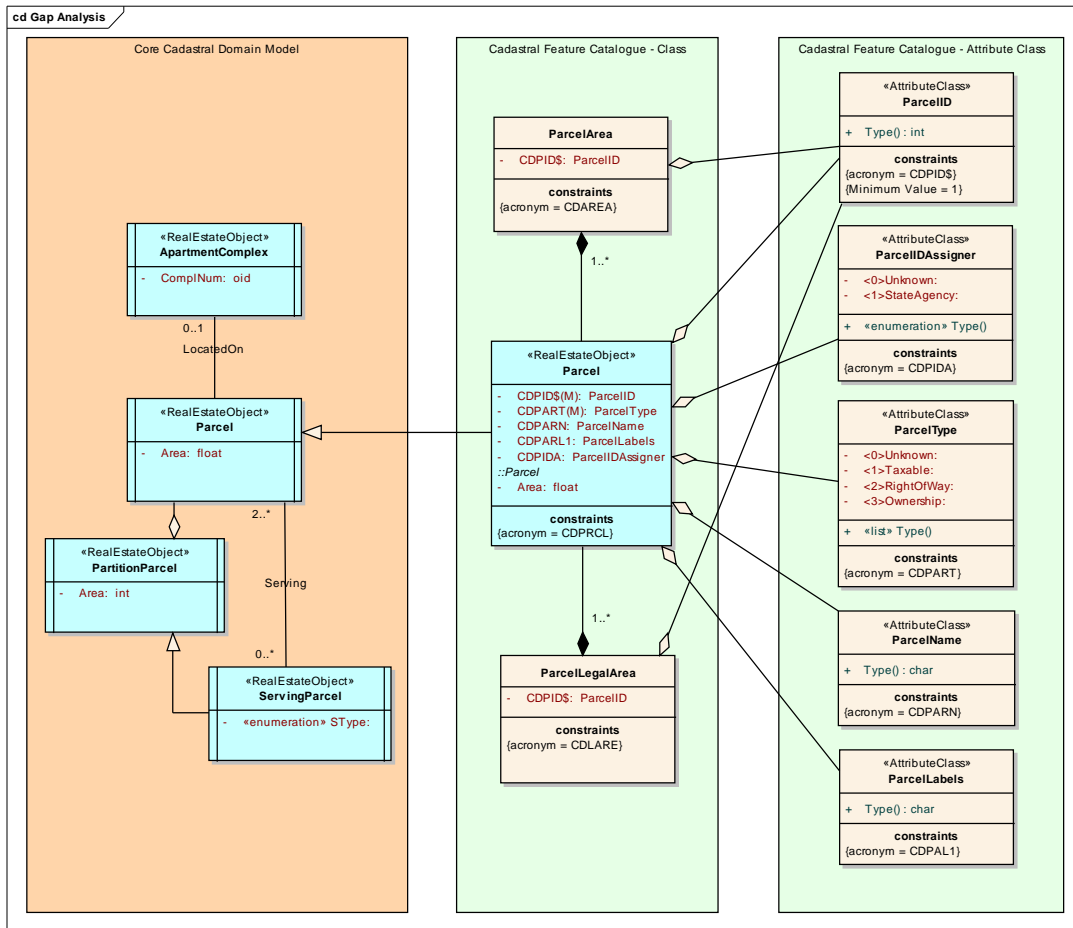Bamberg, Germany, 9 and 10 December 2004

Figure 2 - Example of a Gap Analysis using UML

Following the construction of the FGDC Cadastral Data Content Standard UML model it should be observed that cadastral feature catalogue classes and attribute classes are separated into two data models. This allows for less clutter and confusion since the gap analysis can just be viewed without attribute classes. Also the Core Cadastral Domain Model places an emphasis on classes and their associations.

Since "Parcel" is recognized in both models the presentation (color) and the assignment of a stereotype can be applied in the Standard indicating general commonality. A generalization link can also be establish between the two classes using the Core Cadastral Domain Model as the target or destination since we are looking for compliance with the Model.

An observer can see that though there is a common class in both models there are differences in their association with surrounding classes that are linked to "Parcel". Most notably is that in the Core Cadastral Domain Model area is treated as an attribute will in the FGDC Cadastral Data Content Standard area is treated as a class with attributes.

6. CONCLUSION

The objective of this paper is two fold. First performing a gap analysis provides an effective methodology for comparing existing cadastres with the Core Cadastral Domain Model. Though this can be a daunting task at first glance it is best to work in small packages focusing on areas familiar with domain experts. By first establishing commonality and using an iterative process a proper evaluation can be achieved.

The second objective is designed to provide an opportunity for domain experts to contribute to the discussions involving the development of a Core Cadastral Domain Model. This objective places an emphasis on using a visual presentation available with modeling languages such as UML.

It has been observed by the authors that by using UML presentations domain experts that have little database skills can grasp organizational structures presented in a UML diagram. It is important to get the input of domain experts at an early stage since they may inherit the results of the working group.

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