Development of XML Schemas for Implementation of a 3D Cadastral Data Model

Ali AIEN, Abbas RAJABIFARD, Mohsen KALANTARI, Ian WILLIAMSON and Davood SHOJAEI, Australia

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SUMMARY

A 3D cadastral data model (3DCDM) was developed to support integration of legal and physical information that are required for 3D cadastral applications. The 3DCDM model has twelve sub-models or modules including 3DCDM Geometry Model, 3DCDM Root Model, 3DCDM LegalPropertyObject Model, 3DCDM InterestHolder Model, 3DCDM Survey Model, 3DCDM CadastralPoints Model, 3DCDM Building Model, 3DCDM Land Model, 3DCDM Tunnel Model, 3DCDM UtilityNetwork Model, 3DCDM PhysicalPropertyObject Model, and 3DCDM Terrain Model. Sub-models are selected based on the user requirements and the application. For example, if the purpose of using the 3DCDM model is to model a building and visualise its ownership boundaries, only 3DCDM Building Model and 3DCDM Root Model are used. The 3DCDM Root Model must be used in each implementation of the 3DCDM model.

This paper aims to develop a physical data model of the 3DCDM model. It is developed as an application schema of the Geography Markup Language 3, version GML3.2.1. GML is an XML grammar defined by the Open Geospatial Consortium (OGC) to express geographical features. Each module has a separate schema that support implementation of the 3DCDM model.

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1. INTRODUCTION

The aim of this paper is to convert the logical data model of the 3D Cadastral Data Model (3DCDM) to a physical data model. The physical data model of the 3DCDM has been developed as an application schema of the Geography Markup Language 3, version GML3.2.1. GML is an XML grammar defined by the Open Geospatial Consortium (OGC) to express geographical features (ISO19136, 2007). Accordingly, the physical data model of the 3DCDM is an XML based schema.

The 3DCDM model is decomposed into twelve sub-models (modules). The 3DCDM geometry module is a GML profile. It is a subset of GML (GML3.2.1). GML3.2.1's schema (http://schemas.opengis.net/gml/3.2.1/gml.xsd) is imported into the 3DCDM. Therefore, eleven schemas, one schema per module, are developed. An advantage of having separate sub-models (modules) and also XML schemas is to increase the efficiency of implementation of the 3DCDM model. Users can choose the appropriate module and avoid utilising unnecessary modules.

2. 3DCDM

3D Cadastral Data Model (3DCDM) was developed as a solution capable of supporting 3D data, integrating 3D physical objects with their corresponding 3D legal objects, and featuring semantically enriched objects. The data model is developed based on the ISO standards and UML modelling language is used to specify the data model. The 3DCDM model represents 3D legal objects and connects legal and physical objects together. In this regard, the 3DCDM model is equipped with the concepts of the Legal Property Object (LPO) and the Physical Property Object (PPO). The first facilitates modelling of all existing interests (RRR) as legal objects. The second considers all 3D urban features such as buildings, tunnels, and utilities as physical objects. 3D geometric primitives of GML (Geographic Markup Language) such as Solid and MultiSurface are used to define the Legal and Physical Property Objects. The 3DCDM model supports semantics that define every aspect of legal and physical objects, and therefore, it facilitates their integration.

The *3DCDM* model is composed of two hierarchies: legal and physical. However, they are connected to each other through the associations between their subclasses. The *3DCDM*'s users can navigate through each hierarchy independently and also between hierarchies. Each hierarchy consists of different components and they are all connected to the core component of the *3DCDM* model, which is called the root model. The root model contains the basic features on the *3DCDM* model. The root model must be implemented in any conformant system. The legal hierarchy of the *3DCDM* model comprises of the following components: *LegalPropertyObject*, *Survey*, *CadastralPoint*, and *InterestHolder*. The physical hierarchy has the following components: *PhysicalPropertyObject*, *Building*, *Land*, *Tunnel*, *UtilityNetwork*, and *Terrain*. The *3DCDM* model supports the combination of different legal and physical components to provide more comprehensive cadastral model (Figure 1) (Aien, 2013; Aien et al, 2013a; Aien et al, 2013b; Aien et al, 2011; Shojaei et al, 2012).

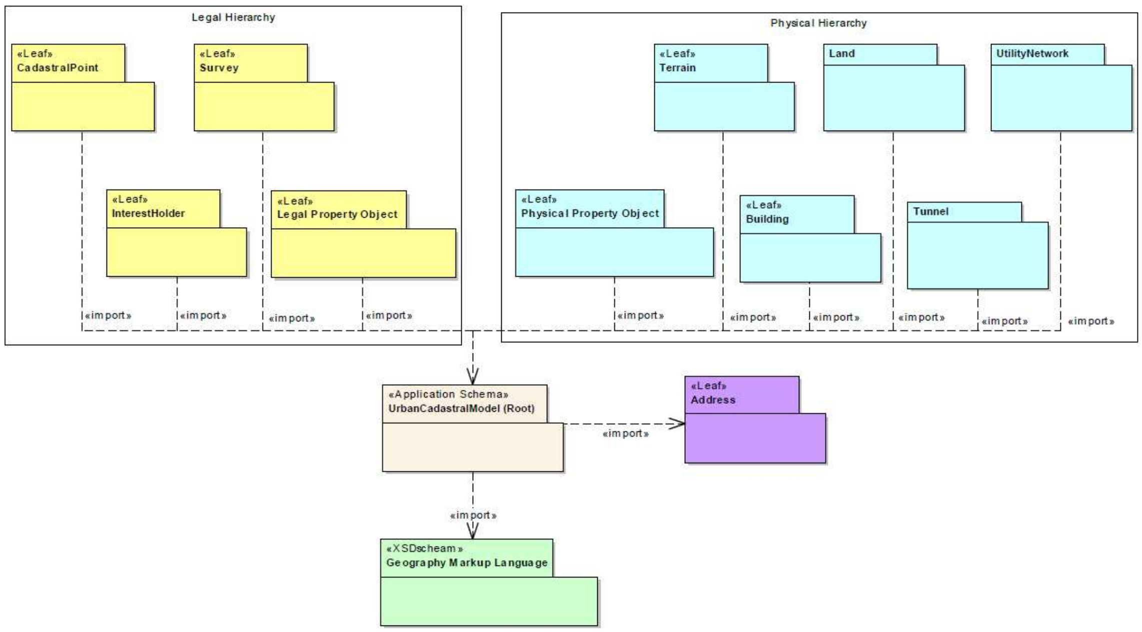

Figure 1. Legal and Physical Hierarchies of the 3DCDM

3. XML SCHEMA

The physical data model of the 3DCDM is represented as XML schemas (11 XML schemas + 1 XML schema of GML3.2.1). An XML schema is a language for expressing constraints about XML documents, in the same way that a database schema describes the data that can be contained in a database. There are several different schema languages in widespread use, but the main ones are Document Type Definitions (DTDs), Relax-NG, Schematron and W3C XSD (XML Schema Definitions) (W3C, 2010). The XML schema defines the shape, or structure, of an XML document, along with rules for data content and semantics such as, what fields an element can contain, which sub elements it can contain, and how many items can be present. It can also describe the type and values that can be placed into each element or attribute. Document Type Definition (DTD) was the first formalised standard but has now, in most cases, been superseded by XSD (LiquidTechnologies, 2012).

4. XML NAMESPACES AND PREFIXES

Defining XML namespaces is an important step in developing XML schemas for the 3DCDM model. XML namespaces are defined to provide unique names and attributes for elements in an XML document. XML namespaces provide a method to avoid element name conflicts. They provide a simple method for qualifying an element and attribute names used in Extensible Markup Language (XML) documents by associating them with namespaces identified by URI references (Bray et al, 2009).
A namespace name is usually a uniform resource identifier (URI). Typically, the URI chosen for the namespace of a given XML vocabulary describes a resource under the control of the author or organisation defining the vocabulary, such as a URL for the author's Web server (Young., 2002).
Eleven namespaces are defined in this section. Every module of the 3DCDM model has a namespace and every namespace is associated with a URI and a suggested prefix. Eleven modules of the 3DCDM and their URIs and suggested prefixes are listed in the Table 1.

Table 1. List of 3DCDM models, URIs and suggested prefixes

3DCDM module	URI	prefix
3DCDM Root	http://www.csdila.unimelb.edu.au/3DCDM/1.0	root
LegalPropertyObject	http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0	lpo
InterestHolder	http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0	ownr
Survey	http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0	suvy
CadastralPoints	http://www.csdila.unimelb.edu.au/3DCDM/cadastralpoint/1.0	cpm
Building	http://www.csdila.unimelb.edu.au/3DCDM/building/1.0	bild
Land	http://www.csdila.unimelb.edu.au/3DCDM/land/1.0	land
Tunnel	http://www.csdila.unimelb.edu.au/3DCDM/tunnel/1.0	tunl
UtilityNetwork	http://www.csdila.unimelb.edu.au/3DCDM/utility/1.0	unwk
PhysicalPropertyObject	http://www.csdila.unimelb.edu.au/3DCDM/ppo/1.0	ppo
Terrain	http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0	tern

Number of standard namespaces and prefixes are used in the 3DCDM. They are listed in Table 2.

Table 2. List of standard namespaces, URIs and their prefixes

Standard model	URI	Namespace prefix
XML Schema	http://www.w3.org/2001/XMLSchema	xs
GML3.2.1	http://www.opengis.net/gml/3.2	gml

5. XML SCHEMA FOR 3DCDM SUB-MODELS (MODULES)

In addition to GML3.2.1's XML schema, eleven XML schemas are prepared to support implementation of the 3DCDM model.

5.1 XML schema for 3DCDM Root model

The *Root* model consists of core features such as *UrbanCadastralModel* and components of the 3DCDM. All other models are connected to the root model. The XML namespace of the 3DCDM Root model (module) is defined by the URI
http://www.csdila.unimelb.edu.au/3DCDM/1.0.
Specifications of the 3DCDM Root model are listed in Table 3.

Table 3. Specifications of the 3DCDM Root model

Model name	3DCDM Root
Model description	The *Root* model consists of core features and components of the 3DCDM. All other models are connected to the root.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/1.0
Suggested namespace prefix	Root
XML schema file	3DCDMBase.xsd

Basic elements of this model are presented below.

5.1.1 <u>UrbanCadastralModel, urbanCadastralModelType</u>

urbanCadastralModelType describes the root element of the 3DCDM model, which is *UrbanCadastralModel*. *UrbanCadastralModel* is a collection of two hierarchies: legal model and physical model. It is also associated with classes *Application* and *MetricUnit*, using *application* and *metricUnit* elements respectively.

```xml
<!-- ============================================================ -->
<xs:element name="UrbanCadatsralModel" type="UrbanCadatsralModelType"
substitutionGroup="gml:AbstractFeatureCollection"/>
<!-- ============================================================ -->
  <xs:complexType name="UrbanCadatsralModelType">
    <xs:annotation>
        <xs:documentation>Type describing the root element of the 3DCDM. UrbanCadastralModel is a collection of two
        hierarchies: legal model and physical model.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="gml:AbstractFeatureCollectionType">
        <xs:sequence>
          <xs:element name="application" type="applicationType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="metricUnit" type="metricUnitType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="physicalModel" type="physicalModelType" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="legalModel" type="legalModelType" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="adminArea" type="xs:string" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================ -->
```

5.1.2 applicationType, Application

applicationType describes the class *Application* of the 3DCDM model and specifies general information (metadata) of the 3DCDM model using attributes *creationDate*, *creationTime*, *creator*, *version*, and *metricUnit.*

```
<!-- ======================================================================================== -->
  <xs:complexType name="applicationType">
    <xs:sequence>
      <xs:element ref="Application" minOccurs="0" maxOccurs="1"/>
    </xs:sequence>
  </xs:complexType>
<!-- ======================================================================================== -->
  <xs:element name="Application">
    <xs:annotation>
      <xs:documentation>Specifies general information (metadata) of the 3DCDM</xs:documentation>
    </xs:annotation>
    <xs:complexType>
      <xs:attribute name="creationDate" type="xs:date" use="optional"/>
      <xs:attribute name="creationTime" type="xs:time" use="optional"/>
      <xs:attribute name="creator" type="xs:string" use="optional"/>
      <xs:attribute name="version" type="xs:string" use="optional"/>
    </xs:complexType>
  </xs:element>
<!-- ======================================================================================== -->
```

5.1.3 metricUnitType, MetricUnit

metricUnitType describes the class *MetricUnit* of the 3DCDM model and specifies the units of the 3DCDM model using attributes *areaUnit, linearUnit, volumeUnit, temperatureUnit, pressureUnit,angularUnit*, and *directionUnit.*

```
<!-- ======================================================================================== -->
  <xs:complexType name="metricUnitType">
    <xs:sequence>
      <xs:element ref="MetricUnit" minOccurs="0" maxOccurs="1"/>
    </xs:sequence>
  </xs:complexType>
<!-- ======================================================================================== -->
  <xs:element name="MetricUnit">
    <xs:annotation>
      <xs:documentation>Specifies the units of the 3DCDM</xs:documentation>
    </xs:annotation>
    <xs:complexType>
      <xs:attribute name="areaUnit" type="areaUnitType" use="required"/>
      <xs:attribute name="linearUnit" type="linearUnitType" use="required"/>
      <xs:attribute name="volumeUnit" type="volumeUnitType" use="required"/>
      <xs:attribute name="temperatureUnit" type="tempUnitType" use="required"/>
      <xs:attribute name="pressureUnit" type="pressureUnitType" use="required"/>
      <xs:attribute name="angularUnit" type="angularUnitType" use="required"/>
      <xs:attribute name="directionUnit" type="angularUnitType" use="required"/>
    </xs:complexType>
  </xs:element>
<!-- ======================================================================================== -->
```

5.1.4 physicalModelType, urbanModelType, physicalObjectMemberType, _UrbanObject, AbstractUrbanObjectType

```xml
<!-- ====================================================================== -->
<xs:complexType name="physicalModelType">
    <xs:sequence>
      <xs:element name="UrbanModel" type="urbanModelType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- ====================================================================== -->
  <xs:complexType name="urbanModelType">
    <xs:annotation>
      <xs:documentation>Type describing the root element of the physical hierarchy (UrbanModel).</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="physicalObjectMember" type="physicalObjectMemberType" minOccurs="0"
      maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- ====================================================================== -->
  <xs:complexType name="physicalObjectMemberType">
    <xs:sequence>
      <xs:element ref="_UrbanObject" minOccurs="0"/>
    </xs:sequence>
  </xs:complexType>
<!-- ====================================================================== -->
  <xs:element name="_UrbanObject" type="AbstractUrbanObjectType" abstract="true"
  substitutionGroup="gml:AbstractFeature"/>
<!-- ====================================================================== -->
  <xs:complexType name="AbstractUrbanObjectType" abstract="true">
    <xs:annotation>
      <xs:documentation>Type describing the abstract superclass of urban objects.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="gml:AbstractFeatureType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ====================================================================== -->
```

physicalModel connects the root element (*UrbanCadastralModel*) to the class *UrbanModel* using *physicalModelType*. *urbanModelType* describes the class *Urban-Model* of the 3DCDM, which is the root element of the 3DCDM's physical hierarcy. *physicalObjectMember* connects the class *UrbanModel* to the abstract class *_Urban-Object* using *physicalObjectMemberType*. *AbstractUrbanObjectType* describes the abstract superclass of urban objects.

5.1.5 _PhysicalPropertyObject, AbstractPhysicalPropertyObjectType, consistsOfPPOType, lpoType

_PhysicalPropertyObject is an abstract class and can be substituted by classes *Building*, *Land*, *Tunnel*, *_UtilityNetwork*, and *PhysicalPropertyObject*. It is a subclass of *_UrbanObject* and is described by *AbstractPhysicalProperty-ObjectType*. *_PhysicalPropertyObject* has a recursive connection with itself using *consistsOfPPO* to describe the aggigation of *_PhysicalPropertyObject*. *consistsOfPPO* is described by *consistsOfPPOType*. It also has a zero or one connection to the class *LegalPropertyObject* (corresponding legal object) using lpo, which is described by *lpoType*.

```xml
<!-- ==================================================================================== -->
  <xs:element name="_PhysicalPropertyObject" type="AbstractPhysicalPropertyObjectType" abstract="true"
  substitutionGroup="_UrbanObject"/>
<!-- ==================================================================================== -->
  <xs:complexType name="AbstractPhysicalPropertyObjectType" abstract="true">
    <xs:annotation>
      <xs:documentation>Type describing the abstract superclass for physical property objects such as buildings, land,
      tunnels, utility networks, etc.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractUrbanObjectType">
        <xs:sequence>
          <xs:element name="consistsOfPPO" type="consistOfPPOType" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="lpo" type="lpoType" minOccurs="0" maxOccurs="1"/>
        </xs:sequence>
        <xs:attribute name="lpoRef" type="xs:IDREF" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ==================================================================================== -->
  <xs:complexType name="consistOfPPOType">
    <xs:annotation>
      <xs:documentation>Type describing the aggregation of physical property objects.</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="_UrbanObject"/>
    </xs:sequence>
  </xs:complexType>
<!-- ==================================================================================== -->
  <xs:complexType name="lpoType">
    <xs:annotation>
      <xs:documentation>Type describing the integration of physical property objects with a legal property object.
      </xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0" maxOccurs="1">
      <xs:element ref="lpo:LegalPropertyObject"/>
    </xs:sequence>
  </xs:complexType>
<!-- ==================================================================================== -->
```

5.1.6 legalModelType, cadastralModelype, legalObjectMemberType, _CadastralObject, AbstractCadastralObjectType

legalModel connects the root element (*UrbanCadastralModel*) to the class *CadastralModel* using *legalModelType*. *legalModelType* describes the class *CadastralModel* of the 3DCDM, which is the root element of the 3DCDM's legal hierarchy. *legalObjectMember* connects the class *CadastralModel* to the abstract class *_CadastralObject* using *legalObjectMemberType*. *AbstractCadastral-ObjectType* describes the abstract superclass of cadastral objects.

```
<!-- ========================================================================== -->
  <xs:complexType name="legalModelType">
    <xs:sequence>
      <xs:element name="CadastralModel" type="cadastralModelType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:complexType name="cadastralModelType">
    <xs:annotation>
      <xs:documentation>Type describing the root element of the legal hierarchy (cadastralModel).</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0" maxOccurs="unbounded">
      <xs:element name="legalObjectMember" type="legalObjectMemberType"/>
    </xs:sequence>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:complexType name="legalObjectMemberType">
    <xs:sequence>
      <xs:element ref="_CadastralObject" minOccurs="0"/>
    </xs:sequence>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:element name="_CadastralObject" type="AbstractCadastralObjectType" abstract="true"
  substitutionGroup="gml:AbstractFeature"/>
<!-- ========================================================================== -->
  <xs:complexType name="AbstractCadastralObjectType" abstract="true">
    <xs:annotation>
      <xs:documentation>Type describing the abstract superclass of cadastral objects.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="gml:AbstractFeatureType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================== -->
```

5.2 XML schema for 3DCDM LegalPropertyObject model

The *LegalPropertyObject* model allows creation and representation of all types of legal objects such as land parcels, 3D parcels, ownerships, easements, and common properties in the 3DCDM model. This model also allows association of legal objects to their physical counterparts. The XML namespace of the 3DCDM LegalPropertyObject model (module) is defined by the URI
http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0.
Specifications of the 3DCDM Root model are listed in Table 4:

Table 4. Specifications of the 3DCDM LegalPropertyObject model

Model name	LegalPropertyObject
Model description	The *LegalPropertyObject* model allows creation and representation of all types of legal objects such as land parcels, 3D parcels, ownerships, easements, and common properties in the 3DCDM. This model also allows association of legal objects to their physical counterparts.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0
Suggested namespace prefix	lpo
XML schema file	LegalPropertyObject.xsd

Basic elements of this model are presented below.

5.2.1 LegalPropertyObject, LPOType

LPOType describes elements, attributes and associations of the class *LegalPropertyObject*. *address* connects *LegalPropertyObject* to the class *Address* using *addressType*. *proprietor* connects *LegalPropertyObject* to the class *InterestHolder* using *proprietorType*. *legalDocument* connects *LegalPropertyObject* to the class *Legal-Document* using *legalDocumentType*. *MultiCurvePropertyType* and *MultiSurface-PropertyType* represent 2D *LegalPropertyObject*. *SolidPropertyType* and *MultiSurface-PropertyType* represent 3D *LegalPropertyObject*. *BoundarySurfaceType* describes the type of surface that is used to define the boundary of the class *LegalPropertyObject*. *address* connects *LegalPropertyObject* to class *Address* using *addressType*. *ppo* connects *LegalPropertyObject* to the abstract class *PhysicalPropertyObject* using *AbstractPhysicalPropertyObjectType*. *LegalPropertyObject* has a recursive connection with itself using *consistsOfLPO* to describe the aggigation of *LegalPropertyObject*. *consistsOfLPO* is described by *consistsOfLPOType*. Attributes of the class *Legal-PropertyObject* are *name*, *lpoFormat*, *lpoUnit*, *rrr*, *lpoClass*, *area*, *volume*, *lot-Entitlement*, *lotLiability*, *landUse*, *lpoState*, and *ppoRef*.

5.2.2 consistsOfLPOType, proprietorType

LegalPropertyObject has a recursive connection with itself using *consistsOfLPO* to describe the aggigation of *LegalPropertyObject*. *consistsOfLPO* is described by *consistsOfLPOType*. *proprietor* connects *LegalPropertyObject* to class *InterestHolder* using *proprietorType.*

5.2.3 legalDocumentType, Title, titleType

legalDocumentType describes the class *LegalDocument* and connects it to the class Title. Class *Title* is described by *titleType*. *titleType* connects class *Title* to the title elements using elements *locatedAs, refersTo*, *loan*, *restrictedBy*, *managedBy*, and *property*. Attributes of the class *Title* are *volume, folio, securityNo, producedDate, producedTime, angularUnit*, and *noOfParentTitle.*

5.2.4 planDescType, landDescriptionType, parentType, parentTitleType

planDescriptionType describes the class *LandDescription*. *landDescriptionType* describes the land description of the title using attributes *lotNo*, *planNo*, *plan*, and *desc*. *parentType* describes the class *ParentTitle*. *parentTitleType* describes the parent title elements using attributes *volume* and *folio*.

5.2.5 loanType, mortgageType, encumbranceType, caveatType, managementType, ownersCorportationsType

loanType describes the class *Mortgage*. *mortgageType* describes the elements of mortgage using attributes *mortgageRef*, *mortgageType*, and *bankName*. *encumbranceType* describes the class *Caveat*. *caveatType* describes the elements of caveat using attributes *caveatRef*, *caveatDate*, and *caveator*. *managementType* describes the class *OwnersCorporations*. *ownersCorporationsType* describes the elements of owners corporations using attribute *ownersCorpPlanNo.*

5.2.6 BoundarySurfaceType, _BoundaryType, AbstractBoundarySurfaceType

BoundarySurfaceType describes the type of surface that is used to define the boundary of class *LegalPropertyObject*. The type of boundary is specified by the abstract class *_BoundaryType*. Abstract*BoundaryType* describes abstract the class *_BoundaryType* using attributes *boundary* and *desc*. *MultiSurfacePropertyType* represents 2D and 3D *LegalPropertyObject*.

5.2.7 VirtualSurface, VirtualSurfaceType, WallSurface, WallSurfaceType, FloorSur-face, FloorSurfaceType, CeilingSurface, CeilingSurfaceType

VirtualSurface, WallSuface, FloorSuface, and *CeilingSuface* describe the type of surface that is used to define the boundary of the class *LegalPropertyObject*. They are described by *VirtualSurfaceType, WallSurfaceType, FloorSurfaceType*, and *CeilingSur-faceType* respectively.

5.2.8 RoofSurface, RoofSurfaceType, SlabSurface, SlabSurfaceType, Suspected-CeilingSurface, SuspectedCeilingSurfaceType, FloorJoistsSurface, FloorJoists-SurfaceType

RoofSurface, *SlabSurface*, *SuspectedCeilingSurface*, and *FloorJoistsSurface* describe the type of surface that is used to define the boundary of class *LegalPropertyObject*. They are described by *RoofSurfaceType*, *SlabSurfaceType*, *SuspectedCeilingType*, and *FloorJoists-SurfaceType* respectively.

5.3 XML schema for 3DCDM InterestHolder model

The *InterestHolder* model maintains information about the land interest holder. This model has an association with the *LegalPropertyObject* model. The XML namespace of the 3DCDM InterestHolder model (module) is defined by the URI
http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0.
Specifications of the 3DCDM InterestHolder model are listed in Table 5.

Table 5. Specifications of the 3DCDM InterestHolder model

Model name	InterestHolder
Model description	The *InterestHolder* model maintains information about the land interest holder. This model has an association with the *LegalPropertyObject* model.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0
Suggested namespace prefix	ownr
XML schema file	InterestHolder.xsd

Basic elements of this model are presented below.

5.3.1 InterestHolder, interestHolderType

interestHolderType describes the elements, attributes, and associations of proprietors using attributes *pName*, *share*, and *type*.

5.3.2 legalDocumentType, propertyType

legalDocumentType describes the elements, attributes, and associations of proprietors using attributes *pName*, *share*, and *type*. *propertyType* connects the interest holder to the property object, which is *LegalPropertyObject*.

5.3.3 addressType, geocodedAddressType, addressPointType

addressType describes the elements, attributes, and associations of the class *Address* using approperiate attributes. A geocoded address is described by *geocodedAddress-Type* and *addressPointType*.

5.4 XML schema for 3DCDM Survey model

The *Survey* model maintains technical and administrative information of surveying and of the surveyor. The XML namespace of the 3DCDM Survey model (module) is defined by the URI http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0.
Specifications of the 3DCDM Survey model are listed in Table 6.

Table 6. Specifications of the 3DCDM Survey model

Model name	Survey
Model description	The *Survey* model maintains technical and administrative information of surveying and surveyor.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0
Suggested namespace prefix	suvy
XML schema file	Survey.xsd

Basic elements of this model are presented below.

5.4.1 Survey, surveyType

surveyType describes the elements, attributes, and associations of the class *Survey* using attributes *jurisdiction*, *legislation*, *purposeofSurvey*, *surveyDate*, *surveyFormat*, *method*, *fieldNoteRef*, and *desc*.

5.4.2 surveyedByType, surveyorType

surveyedByType describes the class *Surveyor*. *surveyorType* describes the surveyor information using attributes *name*, *regNumber*, and *surveyorFirm*.

5.4.3 initialisationType, setupInstrumentType, referencePointType, setupPointType

initialisationType connects the class *Survey* to class *SetupInstrument*. *setupInstrumentType* describes the class *SetupInstrument* using attributes *setupID*, *stationName*, and *instrumentHeight*. *referencePointType* connects the class *Setup-Instrument* to the class *SetupPoint*. *SetupPointType* describes the class *SetupPoint* using element *pntRef*.

5.4.4 observationType, observationGroupType

observationType connects the class *Survey* to the class *ObservationGroup*. *Observation-GroupType* describes the type of observation that is used for surveying.

5.4.5 reducedLineObservationType, redHorizontalLineObservationType

reducedLineObservationType connects the class *ObservationGroup* to the class *red-HorizontalLineObservation*. *redHorizontalLineObservationType* describes the elements and attributes of class *redHorizontalLineObservation*.

5.4.6 reducedArcObservationType, redHorizontalArcObservationType

reducedArcObservationType connects the class *ObservationGroup* to the class *red-HorizontalArcObservation*. *redHorizontalArcObservationType* describes the elements and attributes of the class *redHorizontalArcObservation*.

5.5 XML schema for 3DCDM CadastralPoints model

The *CadastralPoints* model maintains the information related to the survey permanent marks. The XML namespace of the 3DCDM CadastralPoints model (module) is defined by the URI http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0.
Specifications of the 3DCDM CadastralPoints model are listed in Table 7.

Table 7. Specifications of the 3DCDM CadastralPoints model

Model name	CadastralPoints
Model description	The *CadastralPoints* model maintains the information related to the survey permanent marks.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/cadastralpoint/1.0
Suggested namespace prefix	cpm
XML schema file	CadastralPoint.xsd

Basic elements of this model are presented below.

5.5.1 CadastralPoints, cadastralPointsType

cadastralPointsType describes the elements, attributes, and associations of cadastral points.

5.5.2 referencePointMemberType, cadastralPointType

referencePointMemberType and *cadastralPointType* describe the elements, attributes, and associations of a cadastral point.

5.6 XML schema for 3DCDM Building model

The *Building* model allows the creation and representation of various building parts and building structures. This model has an association with the *LegalPropertyObject* model. The XML namespace of the 3DCDM Building model (module) is defined by the URI http://www.csdila.unimelb.edu.au/3DCDM/building/1.0.
Specifications of the 3DCDM Building model are listed in Table 8.

Table 8. Specifications of the 3DCDM Building model

Model name	Building
Model description	The *Building* model allows the creation and representation of various building parts and building structures. This model has an association with the *LegalPropertyObject* model.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/building/1.0
Suggested namespace prefix	bild
XML schema file	Building.xsd

Basic elements of this model are presented below.

5.6.1 Building, BuildingType

buildingType describes the elements, attributes, and associations of the class *Building* using attributes *landUse*, *constructionYear*, *buildingHeight*, *noOfStoreysAboveGround*, *noOfStoreysBelowGround*, *buildingHeightAboveGround*, *buildingHeightBelowGround*.

5.6.2 _BuildingPart, AbstractBuildingPartType

AbstractBuildingPartType describes the abstract class *_BuildingPart* using attributes *area*, *volume*, and *type*.

5.6.3 SpacePropertyType, Space, SpaceType

Abstract class *_BuildingPart* consists of space that are described by *SpaceProperty-Type*. *SpaceType* describes the class *Space* using attributes *area* and *volume*. Each *Space* can be represented by *SolidPropertyType* and *MultiSurfacePropertyType*.

5.6.4 StructuralComponentPropertyType, _StructuralComponent, AbstractStructuralComponentType

Also, abstract class *_BuildingPart* consists of structural components that is described by *StructuralComponentPropertyType*. *AbstractStructuralComponentType* describes the abstract class *_StructuralComponent* using attributes *width*, *length*, *area*, and *volume*.

5.6.5 Wall, WallType, Floor, FloorType, Ceiling, CeilingType

WallType, *FloorType*, and *CeilingType* describe the type of surfaces that are used to define structural components of a building or building part.

5.6.6 Structure, StructureType, Door, DoorType, Window, WindowType

Also *StructuralType*, *DoorType*, and *WindowType* describe the type of surfaces that are used to define structural components of a building or building part.

5.6.7 Unit, UnitType, CarPark, CarParkType, ServiceRoom, ServiceRoomType, StorageRoom, StorageRoomType

UnitType, *CarParkType*, *ServiceRoomType*, and *StorageRoomType* describe the type of building parts.

5.6.8 Pathway, PathwayType, Balcony, BalconyType, Roof, RoofType, BuildingPart, BuildingPartType

PathwayType, *BalconyType*, *RoofType*, and *BuildingPartType* also describe the type of building parts.

5.7 XML schema for 3DCDM Land model

The *land* model allows the creation and representation of the physical land object. This model has an association with the *LegalPropertyObject* model. The XML namespace of the 3DCDM Land model (module) is defined by the URI
http://www.csdila.unimelb.edu.au/3DCDM/land/1.0.
Specifications of the 3DCDM Land model are listed in Table 9.

Table 9. Specifications of the 3DCDM Land model

Model name	Land
Model description	The *land* model allows the creation and representation of the physical land object. This model has an association with the *LegalPropertyObject* model.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/land/1.0
Suggested namespace prefix	land
XML schema file	Land.xsd

5.8 XML schema for 3DCDM Tunnel model

The *Tunnel* model allows the creation and representation of various parts and structures of a tunnel. This model has an association with the *LegalPropertyObject* model. The XML namespace of the 3DCDM Tunnel model (module) is defined by the URI
http://www.csdila.unimelb.edu.au/3DCDM/tunnel/1.0.
Specifications of the 3DCDM Tunnel model are listed in Table 10.

Table 10. Specifications of the 3DCDM Tunnel model

Model name	Tunnel
Model description	The *Tunnel* model allows the creation and representation of various parts and structures of a tunnel. This model has an association with the *LegalPropertyObject* model.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/tunnel/1.0
Suggested namespace prefix	tunl
XML schema file	Tunnel.xsd

5.9 XML schema for 3DCDM UtilityNetwork model

The *UtilityNetwork* model allows the creation and representation of various parts and components of a utility network. This model has an association with the *LegalPropertyObject* model. The XML namespace of the 3DCDM UtilityNetwork model (module) is defined by the URI
http://www.csdila.unimelb.edu.au/3DCDM/utility/1.0.
Specifications of the 3DCDM UtilityNetwork model are listed in Table 11.

Table 11. Specifications of the 3DCDM UtilityNetwork model

Model name	UtilityNetwork
Model description	The *UtilityNetwork* model allows the creation and representation of various parts and components of a utility network. This model has an association with the *LegalPropertyObject* model.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/utility/1.0
Suggested namespace prefix	unwk
XML schema file	UtilityNetwork.xsd

5.10 XML schema for 3DCDM PhysicalPropertyObject model

The *PhysicalPropertyObject* model allows the creation and representation of various unknown physical objects in the 3DCDM. This model has an association with the *LegalPropertyObject* model. The XML namespace of the 3DCDM PhysicalProperty-Object model (module) is defined by the URI
http://www.csdila.unimelb.edu.au/3DCDM/ppo/1.0.
Specifications of the 3DCDM PhysicalPropertyObject model are listed in Table 12.

Table 12. Specifications of the 3DCDM PhysicalPropertyObject model

Model name	PhysicalPropertyObject
Model description	The *PhysicalPropertyObject* model allows creation and representation of various unknown physical objects in the 3DCDM. This model has an association with the *LegalPropertyObject* model.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/ppo/1.0
Suggested namespace prefix	ppo
XML schema file	PhysicalPropertyObject.xsd

5.11 XML schema for 3DCDM Terrain model

The T*errain* model allows creation and representation of the ground surface (TIN or DEM) in the 3DCDM. The XML namespace of the 3DCDM Terrain model (module) is defined by the URI http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0.
Specifications of the 3DCDM Terrain model are listed in Table 13.

Table 13. Specifications of the 3DCDM Terrain model

Model name	Terrain
Model description	The T*errain* model allows creation and representation of the ground surface (TIN or DEM) in the 3DCDM.
Model URI	http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0
Suggested namespace prefix	tern
XML schema file	Terrain.xsd

6. EXAMPLE OF A 3DCDM DATASET

This section illustrates how the 3DCDM model is implemented. A two-storey building consists of three units, one common property, and one easement is chosen as a case study. Figure 2 shows the architectural plan of the building including the location of units and walls' length and width. Figure 3 shows the corresponding legal objects, which are usually represented in subdivision plans. The following sections provide an overview of the case study and related 3DCDM instance documents.

6.1 Dataset

The case study is a two-storey building above ground surface. Each story has 3.0 metre height and the building's total height is 6.0 meters. The walls' width are 0.20 meters. Part of Unit-2's wall is a party-wall and then it is considered an easement for this unit.

Cross-section X-X' represents how the units are vertically located. Part of the building's entrance on the ground floor is a common property with a width of 0.65 metres. The beneficiaries of the common property are Unit-1 and Unit-2. Unit-3's street access is from Trugo Lane.

The ownership boundary between Unit-1 and Unit-2 is the median, symbolised by 'M' in Figure 3. Thus, the wall between Unit-1 and Unit-2 is not a common property. The ownership boundary between Unit-1 and Unit-3 and also Unit-2 and Unit-3 is represented by symbol 'I', which means that the ownership boundary is located in the interior facing wall between Unit-1, Unit-2, and Unit-3. Therefore the wall between Unit-1 and Unit-3 and also Unit-2 and Unit-3 is common property. Other ownership boundaries of Unit-1 and Unit-2 are represented by symbol 'E', which means ownership boundaries are the exterior surface of the wall. Therefore, the building façade in front of Nicholson Street belongs to Unit-1 and Unit-2.

All other boundaries of Unit-3 are interior boundaries. This means the building façade in front of Trugo Lane does not belong to Unit-1 and Unit-2.

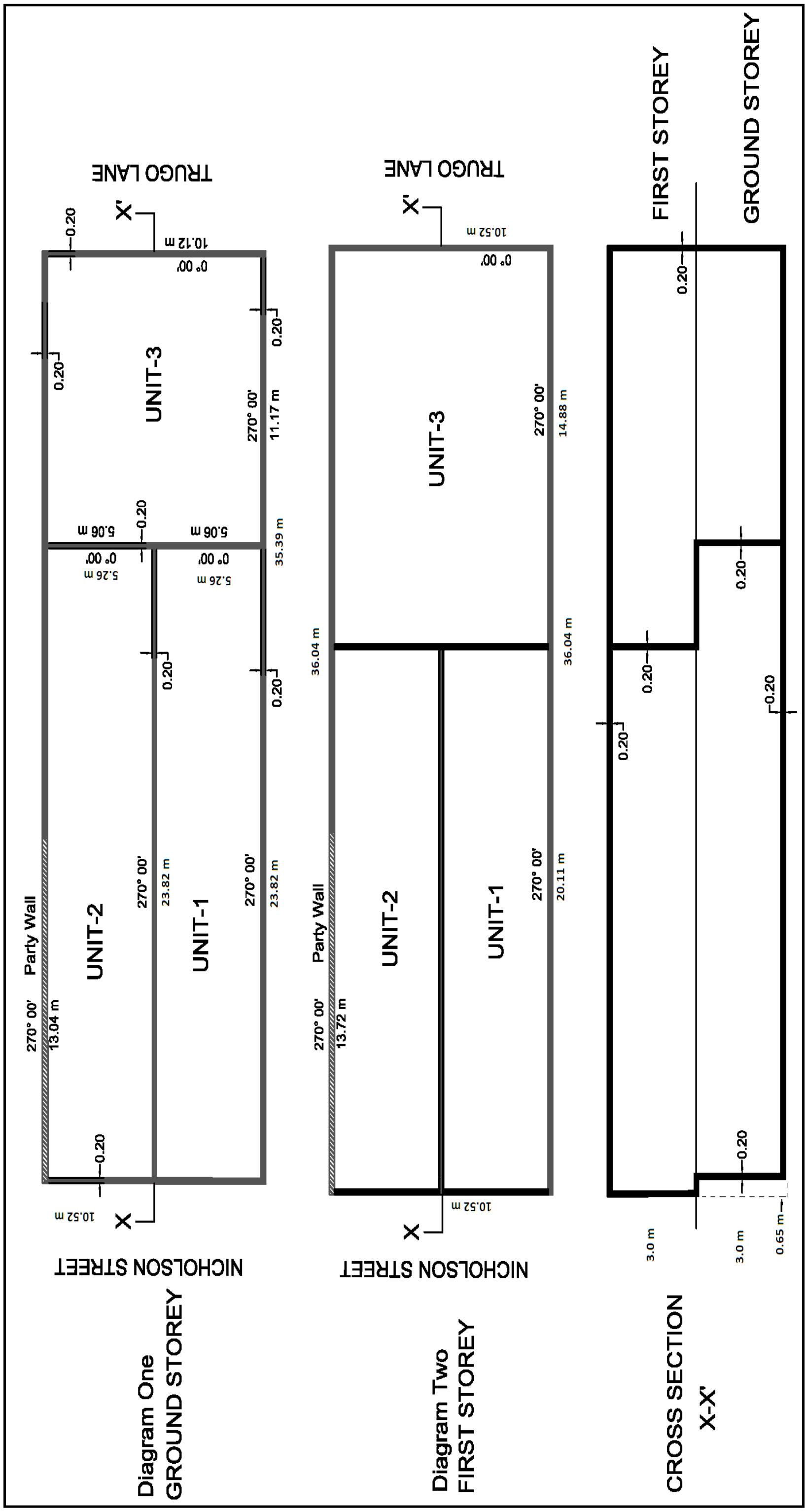

Figure 2. Architectural Plan

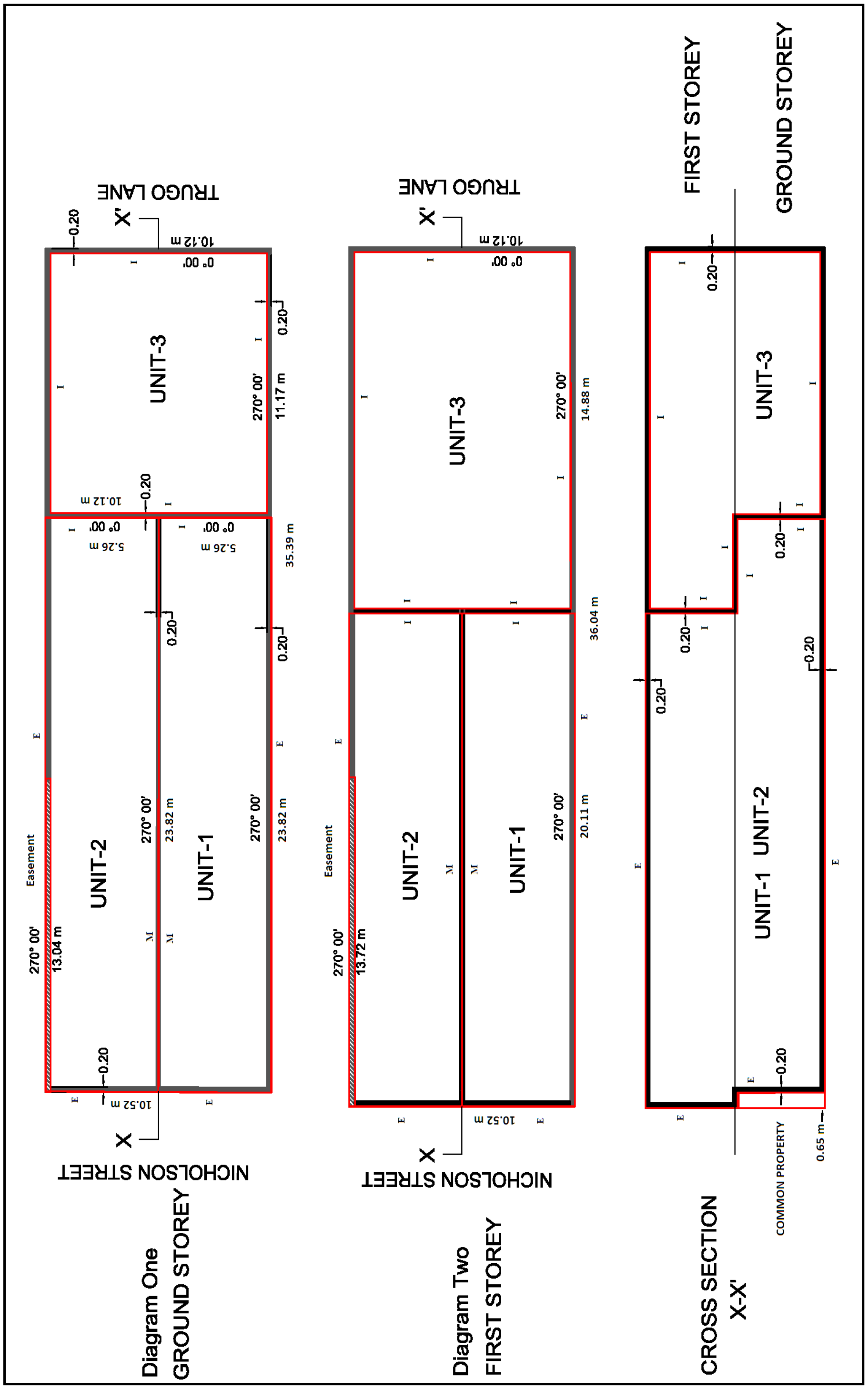

Figure 2. Subdivision Plan

An arbitrary coordinate system is defined to extract all coordinates of the points. The origin of the coordinate system is at the lower left corner of the first story (X = 1000 m, Y = 1000 m) where the X-axis is parallel to the map's horizontal axis and the Y-axis is perpendicular to the X-axis. As a result, all vertices in the plans have known coordinates. From these coordinates, various properties such as width and length of the walls and units can be found.

The following sections represent how an instance of 3DCDM is created to model the legal and physical objects of a 3D building. This example and all XML schemas are edited with XMLSpy v2011 rel. 3 (http://www.altova.com).

6.2 Select and import related modules

The aim of this practice is to model the 3D legal object of the building and their physical counterparts. The first step of using the 3DCDM is to select the modules that are required for the application. Based on the available dataset, the following modules are required to import in the file GML3.2.1, *Building*, *LegalpropertyObject*, *InterestHolder*, *Survey*, *Cadastral-Points*, and Terrain schemas are selected for this practice.

```xml
<!-- ================================ Root Element ================================ -->
<?xml version="1.0" encoding="utf-8"?>
<UrbanCadatsralModel
   gml:id="ID_3DCDM_Example"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
   xmlns:gml="http://www.opengis.net/gml/3.2"
   xmlns:xlink="http://www.w3.org/1999/xlink"
   xmlns:bild="http://www.csdila.unimelb.edu.au/3DCDM/building/1.0"
   xmlns:lpo="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
   xmlns:ownr="http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0"
   xmlns:suvy="http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0"
   xmlns:cpm="http://www.csdila.unimelb.edu.au/3DCDM/cadastralpoint/1.0"
   xmlns:trn="http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0"

   xsi:schemaLocation="
   http://www.csdila.unimelb.edu.au/3DCDM/1.0   http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd
   http://www.csdila.unimelb.edu.au/3DCDM/building/1.0   http://www.csdila.unimelb.edu.au/3DCDM/schema/Building.xsd
   http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0   http://www.csdila.unimelb.edu.au/3DCDM/schema/LegalPropertyObject.xsd
   http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0   http://www.csdila.unimelb.edu.au/3DCDM/schema/InterestHolder.xsd
   http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0 http://www.csdila.unimelb.edu.au/3DCDM/schema/Survey.xsd
   http://www.csdila.unimelb.edu.au/3DCDM/cadastralpoint/1.0 http://www.csdila.unimelb.edu.au/3DCDM/schema/CadastralPoint.xsd
   http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0   http://www.csdila.unimelb.edu.au/3DCDM/schema/Terrain.xsd ">
<!-- ================================ Metadata ================================ -->
```

Project name, coordinate reference system, project boundary, author information (application), and measurement units are specified in the next step.

```xml
<!-- ========================================== Metadata ============================================== -->
  <gml:name>EXAMPLE OF A 3DCDM DATASET- CHAPTER 8</gml:name>
  <gml:boundedBy>
    <gml:Envelope srsDimension="3" srsName=" arbitrary coordinate system">
      <gml:lowerCorner>990 990 0</gml:lowerCorner>
      <gml:upperCorner>1042 1018 10</gml:upperCorner>
    </gml:Envelope>
  </gml:boundedBy>
  <application>
    <Application creationDate="2012-08-29" creationTime="21:00:00" creator="Ali Aien" version="1.0"/>
  </application>
  <metricUnit>
    <MetricUnit directionUnit="decimal dd.mm.ss" angularUnit="decimal dd.mm.ss" temperatureUnit="celsius"
    volumeUnit="cubicMeter" linearUnit="meter" areaUnit="squareMeter" pressureUnit="milliBars"/>
  </metricUnit>
  <!-- ============================================ TIN ============================================-->
```

Combination of terrain and land ownership right objects provides more realistic re-presentation of the legal world. Therefore, the terrain model (TIN) is provided in the first step as below:

```xml
  <!-- ============================================ TIN ============================================-->
  <physicalModel>
    <UrbanModel>
      <physicalObjectMember>
        <trn:Terrain gml:id="DCDM_TIN_1">
          <trn:terrainSource>
            <trn:TIN gml:id="DCDM-TIN-1">
              <trn:tinSource>
                <gml:TriangulatedSurface gml:id="DCDM_tinSurface_1">
                  <gml:trianglePatches>
                    <gml:Triangle>
                      <gml:exterior>
                        <gml:LinearRing>
                          <gml:posList>990 990 0 1042 1018 0 990 1018 0 990 990 0 </gml:posList>
                        </gml:LinearRing>
                      </gml:exterior>
                    </gml:Triangle>
                    <gml:Triangle>
                      <gml:exterior>
                        <gml:LinearRing>
                          <gml:posList>990 990 0 1042 990 0 1042 1018 0  990 990 0 </gml:posList>
                        </gml:LinearRing>
                      </gml:exterior>
                    </gml:Triangle>
                  </gml:trianglePatches>
                </gml:TriangulatedSurface>
              </trn:tinSource>
            </trn:TIN>
          </trn:terrainSource>
        </trn:Terrain>
      </physicalObjectMember>
    </UrbanModel>
  </physicalModel>
  <!-- ==================================== Physical Model =====================================-->
```

The terrain model can be visualised in Figure 4 using FZK Viewer (http://www.iai.fzk.de/www-extern/index.php?id=222&L=1). For this purpose, the 3DCDM's elements are converted to the CityGML elements. FZK Viewer is a CityGML (http://www.citygml.org/) and IFC (http://www.buildingsmart.org/standards/ifc) viewer.

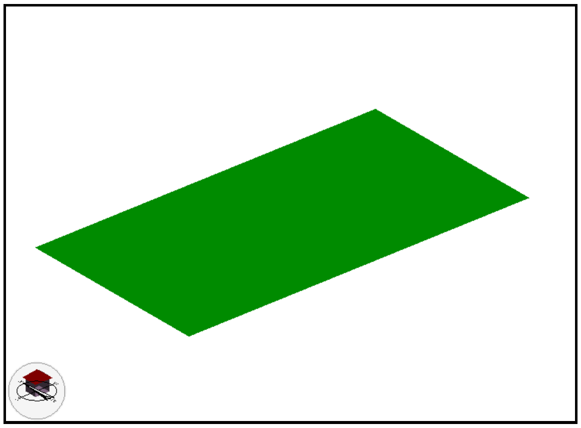

Figure 3. Example of terrain model

A building including three units is modelled in the next steps. This process is conducted in the physical hierarchy of the 3DCDM. *Building* is selected as a *physicalObjectMemeber* of *UrbanModel*. The *Building*'s attributes are provided below:

```
<!-- ========================== Physical Model ========================== -->
<physicalModel>
  <UrbanModel>
    <physicalObjectMember>
      <bild:Building gml:id="DCDM_Building" landUse="residential" constructionYear="1994" buildingHeight="6"
      noOfStoreysAboveGround="2" noOfStoreysBelowGround="0">
        <!-- ======================== Unit1 ======================== -->
```

The *Building* consists of three units. Each unit is a *BuildingPart*. *Unit_1* is introduced in the following codes. The *Unit_1* is a residential unit. In addition, attribute lpoRef="LOT-1" refers the *Unit_1* to its LegalPropertyObject under the name of *LOT-1*.

```
<!-- ======================== Unit1 ======================== -->
<bild:consistsOfBuildingPart>
  <bild:Unit gml:id="DCDM_Unit_1" landUse="residential" lpoRef="LOT-1">
    <gml:name>Unit_1</gml:name>
    <!-- ================ UNIT_1's Legal Counterpart ================ -->
```

Unit_1 is associated with its corresponding legal object (*LOT-1*) in the model. All legal objects are a kind of *LegalPropertyObject* in the 3DCDM model. *LOT-1* is a 3D parcel and represents an ownership space. It is owned by pName="Yamine Family PTY LTD". It is managed by a registered owners corporation ownersCorpPlanNo="PS422525J". Moreover, *LOT-1* is represented by a solid object. The geometry of the solid object is specified using code <lpo:representedBySolid xlink:href="#DCDM_Space_Unit_1"/> which refers to the geometry of another object with the object-id of "#DCDM_Space_Unit_1". *LOT-1* is further described in the model and is represented below:

```xml
<!-- ======================== UNIT_1's Legal Counterpart ============================-->
<lpo>
  <lpo:LegalPropertyObject gml:id="LOT-1" lpoClass="lot" lpoUnit="single" lpoFormat="3DParcel"
  name="LOT-1" lpoState="created" rrr="ownership" lotEntitlement="35" lotLiability="35">
    <lpo:address>
      <lpo:Address flatNumber="1" propertyNumber="143" streetName="Nicholson"
      streetType="street" Suburb="Footscray" postCode="3011" state="VIC" country="Australia"/>
    </lpo:address>
    <lpo:proprietor>
      <ownr:InterestHolder gml:id="ID_101" pName="Yamine Family PTY LTD" share="100"
      type="family"/>
    </lpo:proprietor>
    <lpo:legalDocument>
      <lpo:Title folio="725" volume="10564">
        <lpo:locatedAs>
          <lpo:LandDescription plan="SubdivisionPlan" planNo="422525J" lotNo="1"/>
        </lpo:locatedAs>
        <lpo:refersTo>
          <lpo:ParentTitle folio="283" volume="03422"/>
        </lpo:refersTo>
        <lpo:managedBy>
          <lpo:OwnersCorporations ownersCorpPlanNo="PS422525J"/>
        </lpo:managedBy>
      </lpo:Title>
    </lpo:legalDocument>
    <lpo:representedBySolid xlink:href="#DCDM_Space_Unit_1">
    </lpo:representedBySolid>
  </lpo:LegalPropertyObject>
</lpo>
<!-- ==================== PhysicalPropertyObject ==============================-->
```

The Unit-1 model is shown in Figure 5.

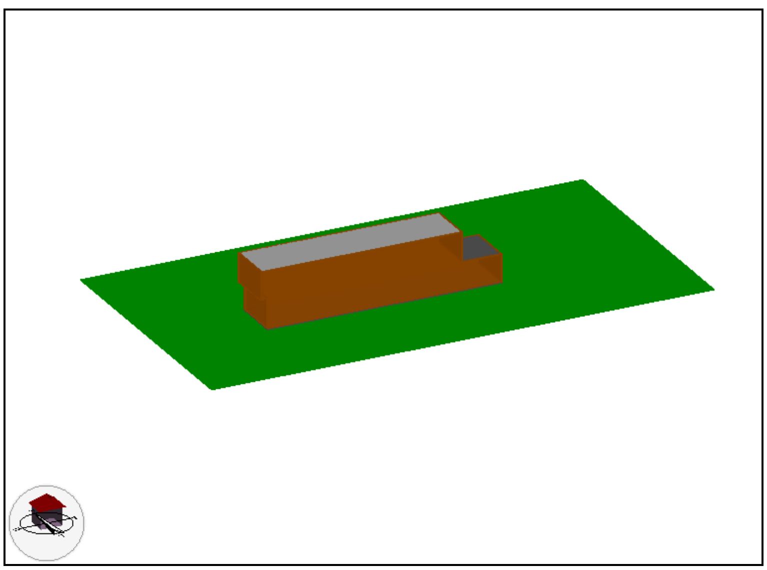

Figure 4. Example of the building model, Unit-1

Unit_2 is created the same as the *Unit_1*. *Unit_2* is a residential unit and is associated with its corresponding legal object (*LOT-2*) in the model *LOT-2* is a 3D parcel and represents an ownership space. It is owned by pName="Jude Sammonds". *LOT-2* is represented by a solid object. The geometry of the solid object is specified using code <lpo:representedBySolid xlink:href="#DCDM_Space_Unit_2"/>, which refers to the geometry of another object with the object id of "#DCDM_Space_Unit_2". The following codes (shortened codes) describe how *Unit-2* is modelled in the 3DCDM model. The Unit-1, Unit-1, and Unit-3 models are shown in Figure 6.

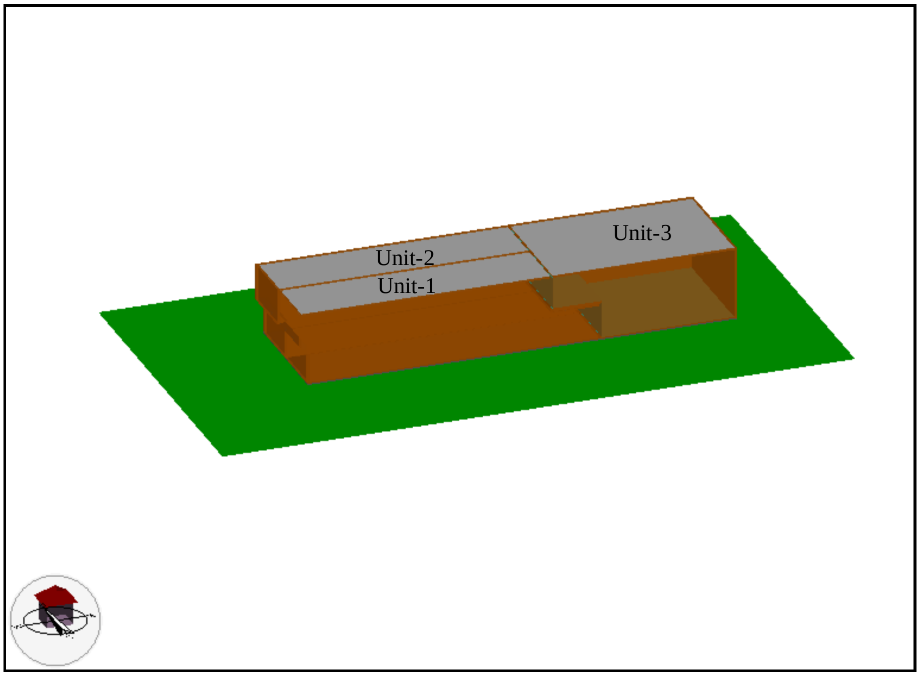

Figure 5. Example of the building model, Unit-1, Unit-2, and Unit3

Figure 7 illustrates the legal counterparts of the building's units. In this Figure, the wall between the Unit-1 and Unit-3 and also Unit-2 and Unit-3 is common property, and it does not belong to the units.

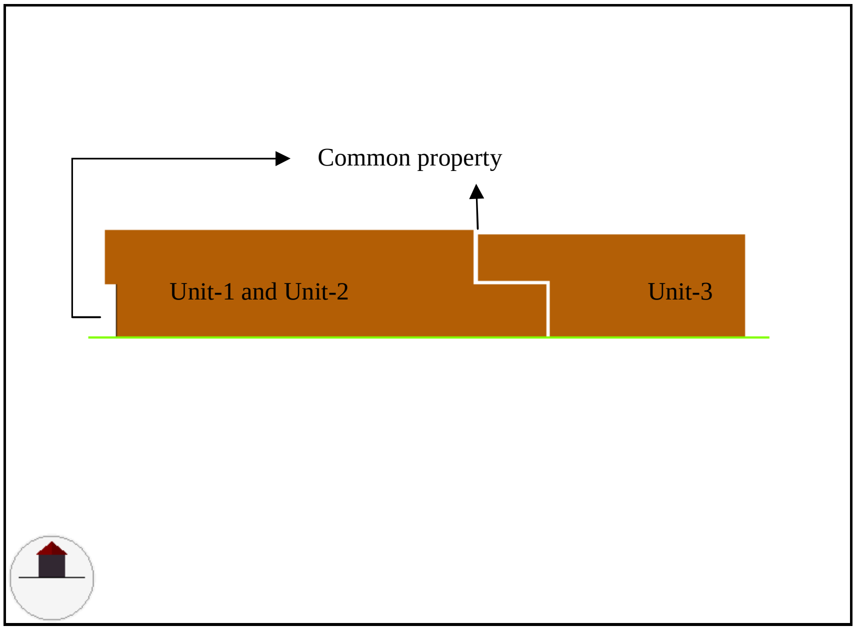

Figure 6. Example of the building model, Unit-1, Unit-2, and Unit3

The previous methods are used to model the *Unit-3* as well. Using the above codes, three units of the *Building* and their legal counterparts are modelled in the 3DCDM. The common property and easement are visualised in the Figure 8.

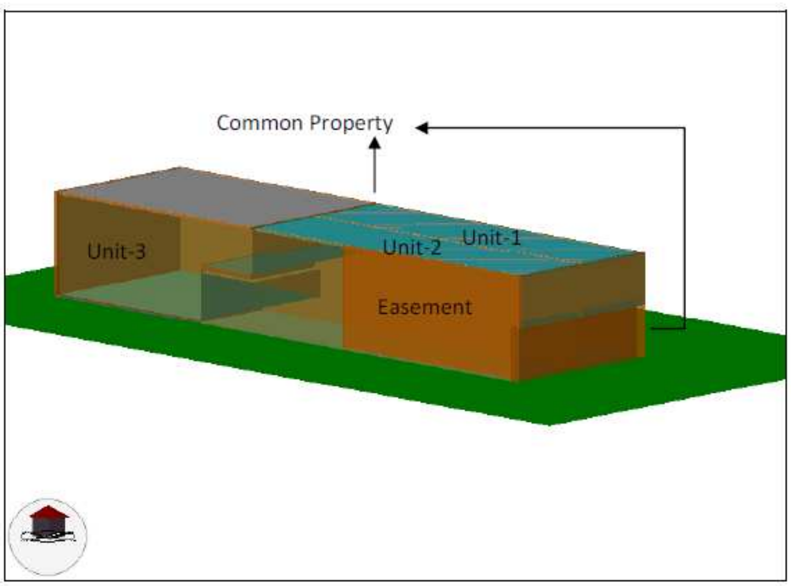

Figure 7. Example of the building model, common property and easement

7. CONCLUSION

In this paper, the physical model of the 3DCDM was presented as the fourth step of 3D cadastral data-modelling development cycle. This step is the last step of the 3DCDM model development. The aim was to implement the 3DCDM model.
For this purpose, eleven XML schemas were developed. One XML namespace, one unique prefix, and one URI were defined per each XML modules. They are summarized in the Table 1. URIs help the model users to access the XML schemas and utilize them to populate their datasets into the XML schemas.
A practical example of a 3DCDM dataset was presented to evaluate how the 3DCDM models the physical objects of a building and their legal counterparts. The dataset is a building that consists of three units, two common properties, and one easement.

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BIOGRAPHICAL NOTES

Ali Aien finished his PhD on 3D cadastral data modeling in 2013 at the Department of Infrastructure Engineering, the University of Melbourne. His research aimed to develop and implement a data model to enable the capture, storage, editing, querying, analysis and support visualization of 3D land rights, restrictions and responsibilities in cadastre. He is currently working as a research assistant in the Centre for Spatial Data Infrastructures & Land Administration (CSDILA).

Abbas Rajabifard is a Professor and Head of Department of Infrastructure Engineering at The University of Melbourne. He is also Director of the Centre for Spatial Data Infrastructures & Land Administration (CSDILA). He is former President of the GSDI Association, a member of ICA-Spatial Data Standard Commission, and a member of Victorian Spatial Council.

Mohsen Kalantari is a Research Fellow at the Centre for SDIs and Land Administration at the Department of Geomatics, the University of Melbourne working on 3D cadastre. He finished his PhD from the University of Melbourne in 2008.

Ian Williamson's teaching and research is concerned with cadastral, land and geographic information systems, land administration and spatial data infrastructures, in both developed and developing countries. He has published extensively on these topics. He has undertaken research or consultancies world-wide including for AusAID, the United Nations and the World Bank. He is a Member of the Order of Australia (AM), a Fellow of the Academy of Technological Sciences and Engineering Australia (FTSE), a Fellow of the Institution of Surveyors Australia Inc., a Fellow of the Institution of Engineers Australia, a Fellow of the Royal Institution of Chartered Surveyors, an Honorary Fellow of the Mapping Sciences Institute, Australia and an Honorary Member of the International Federation of Surveyors (FIG). He was Chairperson of FIG Commission 7 (Cadastre and Land Management) 1994–98 and Director United Nations Liaison for the FIG from 1998–2002. He was a member of the Executive and Chair, Working Group 3 (Cadastre), UN sponsored Permanent Committee on GIS Infrastructures for Asia and the Pacific (2001–2009). At Melbourne he has been President of the Academic Board and Pro-Vice-Chancellor, and was Head of the Department of Geomatics (1987–1993, 1998–2007) and works closely with the Centre for Spatial Data Infrastructures and Land Administration. Awarded the Centenary Medal by the Prime Minister for service to Australian society in research and geomatics engineering and surveying 2003.

Davood Shojaei started his PhD on 3D Cadastral Visualisation in 2010 at the Centre for SDIs and Land Administration at the Department of Infrastructure Engineering, the University of Melbourne. His research aims to develop 3D cadastral visualisation requirements and implement some prototype systems to represent 3D land rights, restrictions and responsibilities in cadastre.

CONTACTS

Ali Aien
University of Melbourne
Parkville
Victoria
AUSTRALIA 3010
Tel.: +61 3 8344 6771
E-mail: aien.a@unimelb.edu.au; ali_aien@yahoo.com
Website: http://www.csdila.unimelb.edu.au/people/ali-aien.html

Abbas Rajabifard
University of Melbourne
Parkville
Victoria
AUSTRALIA 3010
Tel.: +61 3 8344 0234
E-mail: abbas.r@unimelb.edu.au
WebsiteL: http://www.csdila.unimelb.edu.au/people/abbas-rajabifard.html

Mohsen Kalantari
University of Melbourne
Parkville
Victoria
AUSTRALIA 3010
Tel.: +61 3 8344 6833
saeidks@unimelb.edu.au
http://www.csdila.unimelb.edu.au/people/saeid-kalantari-soltanieh.html

Ian Williamson AM
University of Melbourne
Parkville
Victoria
AUSTRALIA 3010
+61 3 8344 5597
ianpw@unimelb.edu.au
http://www.csdila.unimelb.edu.au/people/ian-williamson.html

Davood Shojaei
University of Melbourne
Parkville
Victoria
AUSTRALIA 3010
Tel.: +61 3 8344 5597
E-mail: shojaeid@unimelb.edu.au
Website: http://www.csdila.unimelb.edu.au/people/davood-shojaei.html