3D Cadastral Data Modelling

By

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For my family

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ABSTRACT

The need for more ‘space’ resulting from population growth, urbanisation and industrialisation has increased the pressure on land-use planning and development. As a result, space above and below ground level is increasingly used. Examples include underground developments, infrastructure facilities, high-rise buildings, and apartments. To extend the use and functionality of the land, complex infrastructures are being built, both vertically and horizontally, layered and stacked. These three-dimensional (3D) developments affect the interests attached to the underlying land.

3D cadastres will assist in managing the effects of 3D development and increase the functionality of a multipurpose cadastre. 3D cadastres are digital representations of real property ownership rights, restrictions, and responsibilities (legal objects) and their corresponding physical objects such as buildings, utilities, on, above or under the ground surface. They are equipped with 3D data storage, 3D visualisation, and 3D spatial analysis functions. They facilitate management of property rights; registration of strata plans; and reduction of boundary disputes between owners and Owners Corporations. They also enable a wide variety of applications, which in turn create a demand for detailed and integrated 3D legal and physical objects.

To successfully implement the 3D cadastre and efficiently deliver the above-mentioned objectives, many elements must support a digital 3D cadastre, such as existing 3D property registration laws, appropriate 3D data collection methods, 3D spatial database management systems, and functional 3D visualisation platforms. In addition, an appropriate 3D cadastral data model can also play a key role to ensure successful development of the 3D cadastre. A 3D cadastral data model needs to reflect the complexity and interrelations of 3D legal and physical objects.

Many jurisdictions, organisations and software developers have developed their own cadastral data model. Examples of data-modelling developments are the Core cadastral data model (Henssen, 1995), FGDC Cadastral Data Content Standard for the National Spatial Data Infrastructure (FGDC, 1996), ArcGIS Parcel Data Model (Meyer, 2001), DM.01. (Steudler, 2005), ICSM Harmonised Data Model (ICSM, 2009), ePlan (ICSM,

2009), Legal Property Object (Kalantari et al., 2008), South Korean 3D Cadastre (Lee & Koh, 2007; Park et al., 2010), and ISO 19152- LADM (ISO19152, 2012).

The variation between these data models is the result of the data modellers' different attitudes towards cadastres. They are evidence of the varying expectations of cadastres. However, there are basic common threads among them all. First, most of the current cadastral data models have been developed based on the definition of a 2D land-parcel, neglecting the third dimension. Second, most of the current cadastral data models have been developed purely for legal purposes; therefore they only model legal objects, neglecting integration of physical counterparts of legal objects in the model. Finally, most of the current cadastral data models do not support semantics while modelling the geometry of the objects (legal and physical). Semantically enriched cadastral data models support efficient analysis, thematic queries, data mining, and interoperability in land administration systems. Thus, the current cadastral data models are mostly used for fiscal and legal purposes but not for further applications such as property management, 3D space management, and disaster management that require more complex legal and physical data.

The research problem underpinning this study is therefore: current cadastral data models use a 2D land parcel concept and extend it to support 3D requirements; these data models do not integrate physical counterparts of the legal objects in the model; and they are not semantically enriched. Therefore, these data models cannot adequately manage and represent the spatial extent of 3D RRRs.

To address these problems, this research proposes a 3D Cadastral Data Model (3DCDM) which is a semantic data model for representing 3D legal and physical information that can be shared over different applications. The data model is developed based on the ISO standard and the UML modelling language is used to specify the data model. It is extensible and designed as an open data model, so that XML-based markup languages such as GML can be used as a format of the data model for the storage and exchange of 3D legal and physical models.

3DCDM model has two hierarchies, legal and physical, which are linked in the model. The legal hierarchy is based on Legal Property Object concept and the physical

hierarchy defines the classes and relations for the most relevant objects such as buildings and utility networks with respect to their geometric and semantic properties.

The 3DCDM model aims to achieve a conceptual framework for 3D cadastres, represent key components and their relationships, facilitate subdivision of buildings and strata developments, and integrate physical counterparts of legal objects to support a multipurpose 3D cadastre. The 3DCDM model provides extensive information for 3D cadastre applications. Legal and physical objects are represented by their geometry and semantics. The ability of navigating within two hierarchies (legal and physical hierarchies) independently and between them facilitates selection of appropriate information for applications required by specialist users. Use of this model facilitates implementation of 3D cadastres and increases its usability for different applications.

DECLARATION

This is to certify that:

I. the thesis comprises only my original work towards the PhD;

II. parts of this work have been published in refereed journals or refereed conference proceedings as listed in Appendix A;

III. due acknowledgement has been made in the text to all other material used;

IV. the thesis is fewer than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

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LIST OF ACRONYMS

2D	Two Dimensional
2.5D	Two And Half Dimensional
3D	Three Dimensional
3DCDM	3D Cadastral Data Model (The proposed model in this research)
ABS	Australian Bureau Of Statistics
ACT	Australian Capital Territory
AHD	Australian Height Datum
API	Application Programming Interface
ARC	Australian Research Council
ASCII	American Standard Code For Information Interchange
BIM	Building Information Model
CAD	Computer-Aided Design
CCDM	Core Cadastral Data Model
COM	Component Object Model
CSDILA	The Centre for Spatial Data Infrastructures and Land Administration
DBMS	Database Management System
DERM	Department of Environment and Resource Management
DLL	Dynamic Link Library
DM.01	Data Model Version .01 (Cadastral Data Model of Switzerland)
DSE	The Department of Sustainability and Environment
E-R	Entity Relationship
ERC	Expenditure Review Committee
Esri	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
FIG	International Federation of Surveyors
FOI	Freedom Of Information
FTP	File Transfer Protocol
GIS	Geographic Information System
GML	Geographic Mark Up Language
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSDI	Global Spatial Data Infrastructure
HDM	Harmonised Data Model
ICSM	Inter Governmental Committee On Surveying And Mapping
INTERLIS	Data Exchange Mechanism For Land-Information-Systems
IP	Internet Protocol
LPI	Land and Property Information NSW
ISO	International Standard Organisation
IT	Information Technology
ITC	International Institute For Geo-Information Science And Earth Observation
LA	Land Administration
LADM	Land Administration Domain Model
LASSI	Land And Spatial Survey Information
LPO	Legal Property Object
LRS	Land Registration Services
NSDI	National Spatial Data Infrastructure
NSW	New South Wales
NT	Northern Territories
OGC	Open Geospatial Consortium
OP	Original Plans (Crown)
PAEC	Public Accounts and Estimates Committee
PC	Plan of Consolidation
PDF	Package Definition File
PPO	Physical Property Object

PS	Plan f Subdivision
PSMA	Public Sector Mapping Agencies
RRR	Rights, Restriction, And Responsibilities
SA	South Australia
SDI	Spatial Data Infrastructure
SGV	Surveyor-General Victoria
SII	Spatial Information Infrastructure
SPI	Standard Parcel Identifier
SPEAR	Streamlined Planning through Electronic Applications and Referrals
TAS	Tasmania
UK	United Kingdom
UML	Unified Modelling Language
UN	United Nations
UNECE	United Nations Economic Commission For Europe
URI	Uniform Resource Identifier
URL	Uniform Resource Locators
US	United States
USA	United States of America
VGV	Valuer-General Victoria
VIC	Victoria
VOTS	Victorian Online Title System
VSC	Victorian Spatial Council
WA	Western Australia
WCS	Web Coverage Service
WFS	Web Feature Service
WMC	Web Map Context
WMS	Web Map Service
WWII	World War II
WWW	World Wide Web
XMI	Xml Metadata Interchange
XML	Extended Mark Up Language

CHAPTER 1 – INTRODUCTION

1 INTRODUCTION

The aim of this research is to develop a 3D cadastral data model for managing stratified and overlapping property rights, restrictions and responsibilities. This chapter provides an overview of the problem, describes the overarching research structure, and provides an outline of the subsequent chapters of the thesis.

1.1 RESEARCH BACKGROUND

The need for more ‘space’ resulting from population growth, urbanisation and industrialisation has increased the pressure on land-use planning and development. As a result, space above and below ground level is increasingly used. Examples include underground developments, infrastructure facilities, high-rise buildings, and apartments. To extend the use and functionality of the land, complex infrastructures are being built, both vertically and horizontally, layered and stacked. These three-dimensional (3D) developments affect the interests such as ownership rights attached to the underlying land.

Governments and authorities need to manage land by registering and securing land interests to utilise and develop them in a sustainable and efficient manner. The registration of property rights is one of the key factors around the world that determines economic performance and business activity (Kadaster, 2010). Land administration systems assist in this context.

Management of stratified land rights, restrictions and responsibilities (3D RRRs) is one of the most important challenges in the current land administration systems, which are equipped with cadastres that are only able to maintain 2D spatial information.

Land administration systems are processes to regulate land management policies to manage land by maximising social, economical and environmental benefits for people (Enemark, 2005). Cadastre as an engine of land administration systems plays a significant role to register property rights, restrictions and responsibilities.

Most of the current cadastral systems are two-dimensional (2D) and land parcel based, that is, geometric and descriptive information is based on 2D land parcels, even if the properties have three dimensions. They cannot effectively represent the reality. Current 2D cadastral systems are not able to manage and represent land ownership rights, restrictions and responsibilities in a 3D context (Kalantari et al., 2008). Current 3D registration in most jurisdictions contains 2D paper-based diagrams or drawings as a footprint on deed/title plans or in subdivision plans. They are not included in digital cadastral database (DCDB). Therefore, users cannot interact with the map. It is not possible to measure the length, area, and volume in the system. Query and spatial analysis cannot be executed, because the DCDB does not support 3D data. 3D visualisation is not possible in most jurisdictions, and users cannot go inside the 3D objects and look at the detailed 3D information. 2D cadastres are successfully used for fiscal and legal purposes, and also utilised as base layers in other applications such as disaster management.

The advent of 3D developments such as apartments, high-rise buildings, and complex infrastructures (both above and below ground), has resulted in land administrators attempting to incorporate the third dimension into cadastral systems. The aim is to better enable effective management and registration of 3D property rights, restrictions, and responsibilities (RRRs).

3D cadastres would overcome these problems. A 3D cadastre should be capable of storing, manipulating, querying, analysis, updating, and supporting the visualisation of 3D land rights, restrictions and responsibilities. There is not yet such a system in the world (Godard, 2004; Stoter & Oosterom, 2006; Navratil, 2009; Oosterom, 2010).

A 3D regime should be considered in three main aspects (Figure 1): legal (which supports the register of 3D properties), institutional (which established relationships between involved parties), and technical (which provides platforms to realise the 3D cadastre). These should be considered in 3D cadastre developments for each jurisdiction.

Technical aspects of 3D cadastre vary by content and can be categorised into different subjects based on their objectives (Figure 1.1):

- 3D data capturing: researching on what types of 3D cadastral objects need to be collected (buildings, pipelines, tunnels, etc.) and what methods of 3D data capturing can be used to capture 3D data (land surveying, aerial photogrammetry, laser scanning, etc.). Integration of different 3D data capturing methods is one solution in this research area, while cross-sections are being used to determine vertical aspects of 3D cadastral objects.

- 3D data representation: Visualising 3D cadastral objects, 3D analyses and 2.5D earth surface in vector and raster formats. 3D GIS and CAD systems can provide this opportunity. 2D paper-based plans are being used to represent 3D data in most cadastral systems (Shojaei et al., 2012).

- Cadastral updating: updating cadastral objects in DCDB. Geometry and topology of 3D cadastral objects are complex and they need to be maintained in a 3D DBMS. Currently 2D DBMSs are being used for 3D cadastre.

- 3D data modelling: developing data models to identify 3D objects and their relationships. 3D cadastral data modelling will enable the capture, manipulation, analysis and support visualisation of 3D land rights, restrictions and responsibilities. Most of the existing cadastral data models are 2D, such as the ePlan data model (ICSM, 2009), which is restricted in its cover to a few 3D objects such as volumetric lots.

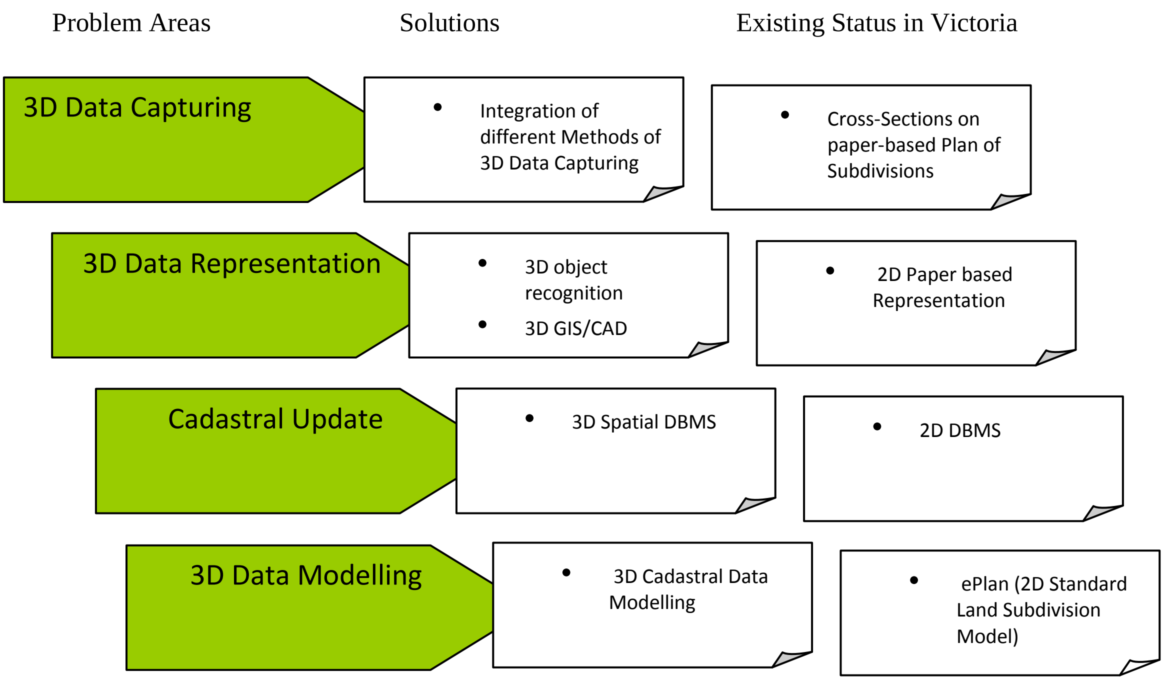


Figure 1.1: Technical aspects of 3D cadastre

The 3D cadastre concept emerged in the early 2000s. An initial workshop was held in 2001 (Delft, The Netherlands); a second followed in 2011 (Delft, The Netherlands) and third in 2012 (Shenzhen, China). In the interim, numerous theoretical and practical developments emerged (Hillman, 1983; Bełej et al., 2002; Grinstein, 2003; Godard, 2004; Stoter, 2004; Arens et al., 2005; Paasch, 2005; Chai, 2006; Paulsson, 2007; Khuan et al., 2008; Döner et al., 2010; Ericsson & Jansson, 2010; Karki et al., 2010; Zhu & Hu, 2010; Acharya, 2011; Breunig & Zlatanova, 2011; Carneiro et al., 2011; Döner & Biyik, 2011; Ekbäck, 2011; Erba & Graciani, 2011; Frédéricque et al., 2011; Griffith-Charles & Sutherland, 2011; Iván, 2011; Khoo, 2011; Navratil & Unger, 2011; Sørensen, 2011; Bydlosz, 2012; Chiang, 2012; Choon & Hussin, 2012; Dimopoulou & Elia, 2012; Elizarova et al., 2012; Erba & Piumetto, 2012b, 2012a; Frank et al., 2012; Gal & Doytsher, 2012; Guo et al., 2012a; Guo et al., 2012b; Hendriatiningsih et al., 2012; Jeong et al., 2012; Khoo, 2012; Mangioni et al., 2012; Paasch, 2012; Wang et al., 2012). However, as yet there is no true 3D cadastre implemented anywhere in the world (Oosterom et al., 2011).

There are several reasons why 3D cadastres have not been successfully implemented: legal, institutional, and technical aspects all play a role. Specific reasons include the lack of:

- legal support and mandate to register 3D properties (legal and institutional issues)
- a clear scope for 3D cadastres (institutional issues)
- specified guidelines and standards for surveyors to capture required 3D data, and a lack of data formats to integrate and exchange 3D data (legal, institutional and technical issues)
- business cases and cost-effective analysis for implementing 3D cadastres (conversion or integration of existing systems to 3D, capture of new data), (institutional and technical issues)
- available technologies for storing, manipulating, and visualising 3D objects (technical issues)

- most importantly, a comprehensive data model capable of advancing implementation.

Although all legal, institutional and technical aspects of a 3D cadastre provide the framework for its successful development and implementation, data modelling is one of the most important elements of a successful 3D cadastre. As architectural models of houses and high-rise buildings help their users visualise the final product, 3D cadastre data model supports 3D cadastre users to understand the structure or behaviour of the system and has a template that guides them to construct and implement the 3D cadastre. 3D cadastre data model supports 3D cadastre users to understand the structure or behaviour of the system and has a template that guides them to construct and implement the 3D cadastre.

A 3D cadastral data model can provide:

- exploration of the different parts of 3D cadastres (objects, elements, attributes, and constraints) and how they are arranged
- organisation and provision of documents and practical guidelines for land surveying professionals
- simplification of the process of implementing 3D cadastres
- promotion of standards and a common language within the land administration user communities
- a foundation of a 3D cadastre database
- facilitation of the exchange of data and the integration of similar datasets, and ease data sharing and interoperability
- an understanding of the data requirements of the involved parties.

Overall, a 3D cadastral data model can provide a framework and template to define and explore the 3D cadastre and to facilitate its implementation. It also can throw into light the numerous demands and unanswered questions of 3D cadastres, including:

- What are the application areas of 3D cadastres? Should 3D cadastre only be implemented in CBDs (Central Business Districts), in entire urban areas including all above and underground infrastructures, or even in rural areas, including underground pipelines and mines?
- What is the purpose of 3D cadastres? Should 3D cadastre serve fiscal and legal purposes, or should it be a multipurpose cadastre?
- What objects should be registered in 3D cadastres? Should only legal spaces (RRRs and public law restrictions) be registered, or should physical objects such as buildings, units, and pipelines be registered in 3D cadastres?
- What is the level of detail required of a 3D cadastre? Should 3D cadastres be multi-scale systems and include as much as detailed information as possible, or should they only represent empty volumes?

There have been different cadastral data models since cadastral mechanisation. Many jurisdictions, organisations and software developers have developed their own cadastral data models. The variation between the data models is the result of the author's different attitudes towards cadastres. They are evidence of the varying expectations of land administration systems. Examples of current cadastral data models include:

- The core cadastral data model (Henssen, 1995)
- FGDC Cadastral Data Content Standard for the National Spatial Data Infrastructure (FGDC, 1996)
- ArcGIS Parcel Data Model (Meyer, 2001)
- The Legal Property Object Model (Kalantari et al., 2008)
- ePlan (ePlan, 2010)
- ISO 19152, Land Administration Domain Model (LADM) (ISO19152, 2012).

Data models are normally developed according to specific purposes. Data modellers decide how to model the data to fit the type of problems they are trying to solve. Since land administration requirements differ among the different jurisdictions, various cadastral data models have been developed around the world. However, there are three basic common threads among them all.

First of all, current cadastral data models have been developed based on the definition of a 2D land-parcel, and most of the existing data models only cover 2D land-parcels (Kalantari et al., 2008). Of course, some have 3D objects as components of the data model. 3D cadastres are currently being developed in the context of 2D cadastres, yet it is argued that it is the 2D cadastre that should be accommodated within the context of a 3D cadastre (Aien et al., 2011b).

Secondly, current cadastral data models mostly include legal information to serve for legal or a fiscal purpose, and they do not incorporate physical information (building structures such as walls, ceilings, roofs) with legal information (RRRs such as ownership and right of use information).

Land administration includes diverse but related functions such as land tenure, land value, land use, and land development. Traditionally land administration functions have been founded on land parcels. Although cadastral systems were mainly established to serve a legal or a fiscal purpose, the data of the cadastral systems are also used for facilities management, base mapping, value assessment, land-use planning, real estate management, environmental impact assessment, environmental simulation, mobile telecommunication, disaster management city planning, architectural design, and tourist. A legal basis, however, does not exist everywhere for all of these other purposes (Kaufmann & Steudler, 1998).

The multipurpose 3D cadastres would provide better and more efficient service to the public and private clients. However, 3D cadastres need considerable investment. A 3D cadastre cost/benefit analysis would be needed to demonstrate that the detailed 3D information can serve as a multipurpose 3D cadastre in different domains.

Applications of 3D cadastre are different and they require a different detail and scale of information. For example, land registrars need parcel scale information, meaning that they need to register and visualise subdivided 3D spatial objects and their associated rights. By contrast, city-planning organisations need large scale and more detailed information in every unit and storey of a building.

User expectations are for 3D RRRs to be visualised in a 3D cadastre. However, visualising 3D RRRs alone would not adequately assist management of 3D RRRs. The actual construction of the buildings should be visualised in different details for different land administration functions (Aien et al., 2011c).

Finally, current cadastral data models have been defined as purely legal models, neglecting the full semantic aspects, that is, spatial objects of these data models are not assigned to semantic objects that represent their spatial properties. For example, LADM defines *boundary face* and *boundary face string* concepts for 2D and 3D representations of spatial units; however, these classes are not assigned to semantic objects, then, it is not possible to define the type of the boundary whether it is a wall, ceiling, or floor surface. Thus, these models could almost only be used for covering terminologies and basic information-related components of land administration.

On the semantic level, current cadastral data models represent legal world entities by defining objects, for example party (interest holders' information), administrative units or legal documents (rights, restrictions, and responsibilities), and spatial units (geometric and surveying information of land 2D and 3D parcels) including attributes, relations and aggregation hierarchies between objects. On the spatial level, geometric objects are not assigned to semantic objects.

The advantages of having a full semantic land administration model is the possibility of navigating in or between both semantic and geometric levels, and facilitating differentiation between land administration and property objects (wall, roof, ceiling). A semantically enriched land administration model supports the need for efficient analysis, thematic queries, or data mining in land administration systems.

The final product of a 3D cadastral system is a 3D digital platform. It would contain all legal objects and related physical objects. Data models of such a system should consider all legal objects including buildings, tunnels, utilities, mines and etc.

Considering terrain surface would support the need to specify and clarify the relations among property objects. Not only are land parcels situated on a 3D terrain surface, but also the ground and underground levels of buildings, and they are influenced by the slope and aspect of adjacent terrain surfaces. Accommodating the terrain surface, in addition to cadastral and city information, in land administration models would serve different applications such as flood simulation, which is useful for insurance and disaster management.

The solution to solve the shortcomings of the current land administration and cadastral models for 3D cadastral purposes is to develop a 3D Cadastral Data Model that accommodates 3D parcels, incorporates legal and physical information, and is semantically enriched.

1.2 RESEARCH PROBLEM

Cadastres are regarded as the engine of land administration systems to help manage interests in land and its resources. 3D developments of land are common and put enormous pressure on current land administration systems that are equipped with the cadastres that are only able to maintain 2D spatial information.

In dense urban populated areas, current land administration systems use 2D cadastral data models which:

a) *do not efficiently facilitate representation and analysis of 3D data.*

b) *are not semantically enriched*

c) *do not incorporate physical objects.*

Therefore they cannot adequately manage and represent the spatial extent of stratified land rights, restrictions and responsibilities (RRRs).

1.3 RESEARCH HYPOTHESIS

In considering the research problem, the research hypothesis was formulated as follows:

- *A 3D cadastral data model will improve current land administration systems to better manage stratified (3D) land rights, restrictions and responsibilities in the dense urban populated areas.*

To test the hypothesis, dividing it into more specific research questions lead to the definition and testing of measurable variables.

1.4 RESEARCH QUESTIONS

In considering the research problem and hypothesis, key research questions were formulated as follows:

- *What is a 3D cadastral data model? How can it help to explore and understand 3D cadastres?*

- *Why cannot current cadastral data models manage and stratify RRRs efficiently? Is there a need to develop a new data model to support the concepts of 3D cadastre?*

- *What are the data sources of the 3D cadastre? How many data sources are there to provide information for a 3D cadastral data model?*

- *What should be represented in the 3D cadastre? What are the business requirements for developing a 3D cadastral data model? What type of objects, attributes should be recorded in a 3D cadastral data model? How many RRRs do exist and should be considered in a 3D cadastral data model? How many components should a 3D cadastral data model have? How should a 3D cadastral data model provide the need of the multi-purposes 3D cadastre?*

- *What are the requirements to implement the 3D cadastral data model? What type of geometrical objects should be considered in the 3D cadastral data model being able to represent stratified RRRs?*

- *How can a data model be designed and developed to accommodate the requirements of 3D cadastres and interactions between all legal and physical objects?*

Using these research questions as the basis for exploring 3D cadastral systems, the following research aim and objectives were formulated to achieve the research question.

1.5 RESEARCH AIM

In recognising the research problem and research questions, the central aim of the research is to:

Develop and implement a data model to enable the capture, storage, editing, querying, analysis and support visualisation of 3D land rights, restrictions and responsibilities in cadastres.

1.6 RESEARCH OBJECTIVES

To achieve the research questions and aim of the research, the following objectives were considered to:

1. *investigate concept, definition and requirements of 3D cadastres*
2. *investigate and assess current cadastral data models*
3. *identify the user requirements and main data elements of 3D cadastres*
4. *design and develop a 3D cadastral data model suitable for land administration systems*
5. *develop a prototype to test the 3D cadastral data model using a case study.*

1.7 RESEARCH APPROACH

This thesis follows a mixed research process that integrates the qualitative approach to explore the deficiencies of current cadastral data models in terms of accommodating 3D information and the case study approach. The case study approach is a suitable method to investigate the current practice of 3D property registration and identify how 3D cadastral systems should be developed to improve the current process. The use of mixed methods can also minimise the weakness of a single approach through the complementary utilisation of the strengths of other methods.

Furthermore, the opportunity to investigate and present a greater diversity of views is important in validating the research findings (McDougall, 2006). Divergent findings are valuable in that they lead to the re-examination of the conceptual framework and underlying assumptions of each of the two components (Tashakkori & Teddlie, 2010). The diversity and divergence of perspectives between the stakeholders of 3D cadastre including registrars, surveyors, architects, and owner corporation industries, provides this opportunity to improve the quality of the data model.

The research approach consists of three major phases:

- conceptual phase
- design phase
- implementation phase.

It concludes in the development of a research framework to address the research question. Figure 1.2 describes the utilised research approach.

The conceptual phase investigates the concept and requirements of 3D cadastres and spatial data modelling. In this phase, the research focuses on the underlying concept of 3D cadastre to investigate the definition, importance, characteristics, aspects, and requirements of 3D cadastres. There is an additional focus on spatial data modelling in this phase including an investigation of a data modelling development cycle and related data modeling standards. Current cadastral data models are also evaluated in this phase. The aim is to identify issues, obstacles and complications as well as successful experiences and best practices in accommodating the requirements of 3D cadastres. Examples include the core cadastral data model, FGDC, ArcGIS Parcel Data Model, DM.01, The Legal Property Object Model, ICSM Harmonised Data Model, ePlan, LADM. Finally, observing case studies complements this phase by addressing the issues of current practice of 3D property registration and identifying important factors that should be considered in 3D cadastral data model development process. This research investigates one case study from Victoria, Australia: a complex underground car park.

After the conceptual phase, the design phase starts by proposing and designing a new 3D Cadastral Data Model (3DCDM). The aim is to design the 3DCDM model to enable the capture, storage, editing, querying, analysis and support visualisation of 3D land rights, restrictions and responsibilities in cadastres which incorporates legal and physical information, and supports semantic.

In the implementation phase, the proposed logical data model of the 3DCDM is converted 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. Accordingly, the physical data model of the 3DCDM is an XML based schema. XML schemas organise the data as schema instances. The 3DCDM model is decomposed into twelve sub-models (modules). The 3DCDM geometry module is a GML profile. Therefore, eleven XML schemas, one schema per module, are developed as the implementation phase of this research. 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.

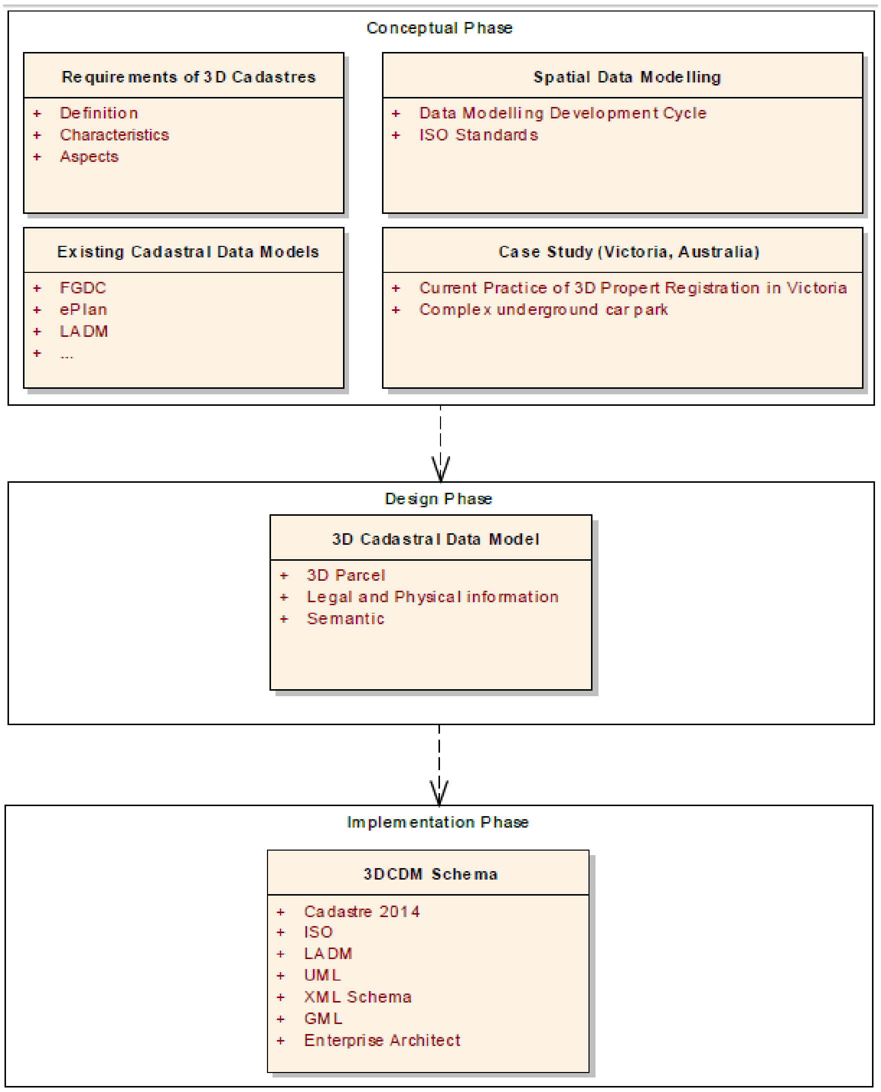


Figure 1.2: Research Approach

The 3DCDM model proposed in the design phase is developed during the implementation phase. A logical data model is developed in the design phase, which is compatible with ISO standards and OGC specifications in the domain of spatial industry and global land administration statements. The Unified Modelling Language (UML) is used to develop the 3DCDM model. The research incorporates the logical model using Enterprise Architect modeling capabilities and GML specifications to design a GML-based application schema to physically implement the 3DCDM model in a computer environment.

1.8 THESIS STRUCTURE

The thesis is structured in four main parts. Part one is the introduction and consists of the statement of the research problem, research question, research aim and objectives. The research problem is described and an overview of the research approach is presented. Part 2 contains the background chapters that review theory and practice. Part 3 consists of the research methodology, case study analysis and the results of the comparison and evaluation. Part 4 comprises of the model development, physical implementation, discussion and conclusions. Figure 1.3 illustrates the structure of the thesis and its relationship to the research objectives.

In Chapter 1, the background to the research problem is presented. The research question and the overall aim of the research are stated and the objectives to achieve this aim are presented. An overview of the research approach is provided.

Chapter 2 investigates 2D cadastres and identifies its problems in terms of accommodating 3D data. The needs for 3D cadastres are described in the context of the rapid 3D development above and under the ground in urban areas. 3D cadastre definition, importance, objectives, and applications are described and 3D cadastre aspects are illustrated to understand legal, institutional and technical issues that limit the development of 3D cadastres. Data modelling development cycle, related ISO standards are reviewed.

Chapter 3 describes the qualitative assessment results of the current cadastral data models to identify issues, obstacles and complications as well as successful experiences and best practices in accommodating the requirements of 3D cadastres. This assessment assists the research by providing a detailed understanding of the different views towards cadastral systems.

Chapter 4 describes the research design and methods and aims to develop a strategy to achieve the objectives defined in the first chapter. A mixed methods approach is selected and justified as the basis to explore the deficiencies of current cadastral data models in terms of accommodating 3D information to investigate the current practice of

3D property registration and identify how 3D cadastral systems should be developed to improve the current process.

Chapter 5 describes and analyses one case study to review the current practice of 3D property registration in Melbourne (Victoria), Australia. An underground car park has been selected as a case study. The aim of this Chapter is to investigate the deficiencies of current practice of 3D property registration and identify the requirements to improve the system.

Chapter 6 uses the outcomes of previous chapters and describes initiatives to consider in current cadastral systems. In response to the research problem, three initiatives are proposed based on the requirements of 3D cadastres. The proposal, firstly, expands the capability of current cadastral data models' building blocks to support 3D information; secondly, it improves the misrepresentation of legal information using incorporation of legal and physical objects; finally, it semantically enriches the data models making it possible for efficient analysis and thematic queries. The conceptual model of the 3DCDM is developed in this chapter based on international standards such as ISO and OGC and global land administration statements like Cadastre 2012 and land administration standards like LADM. Components, classes and relationships between them are described.

The logical model of the 3DCDM is developed in Chapter 7. The 3DCDM model consists of eleven modules (sub-models). All modules are explained in detail in this chapter. UML is used by Enterprise Architect software to illustrate all classes, attributes and relationships of the 3DCDM model.

Chapter 8 presents the physical model of the 3DCDM. Eleven XML schemas as GML application schemas are developed and explained for this purpose in this chapter. An example of the 3DCDM model dataset is presented to describe how various XML schemas are implemented.

Chapter 9, finally, presents the research achievements and conclusions. The significance of the research findings to theory and practice are examined and recommendations for further research are provided.

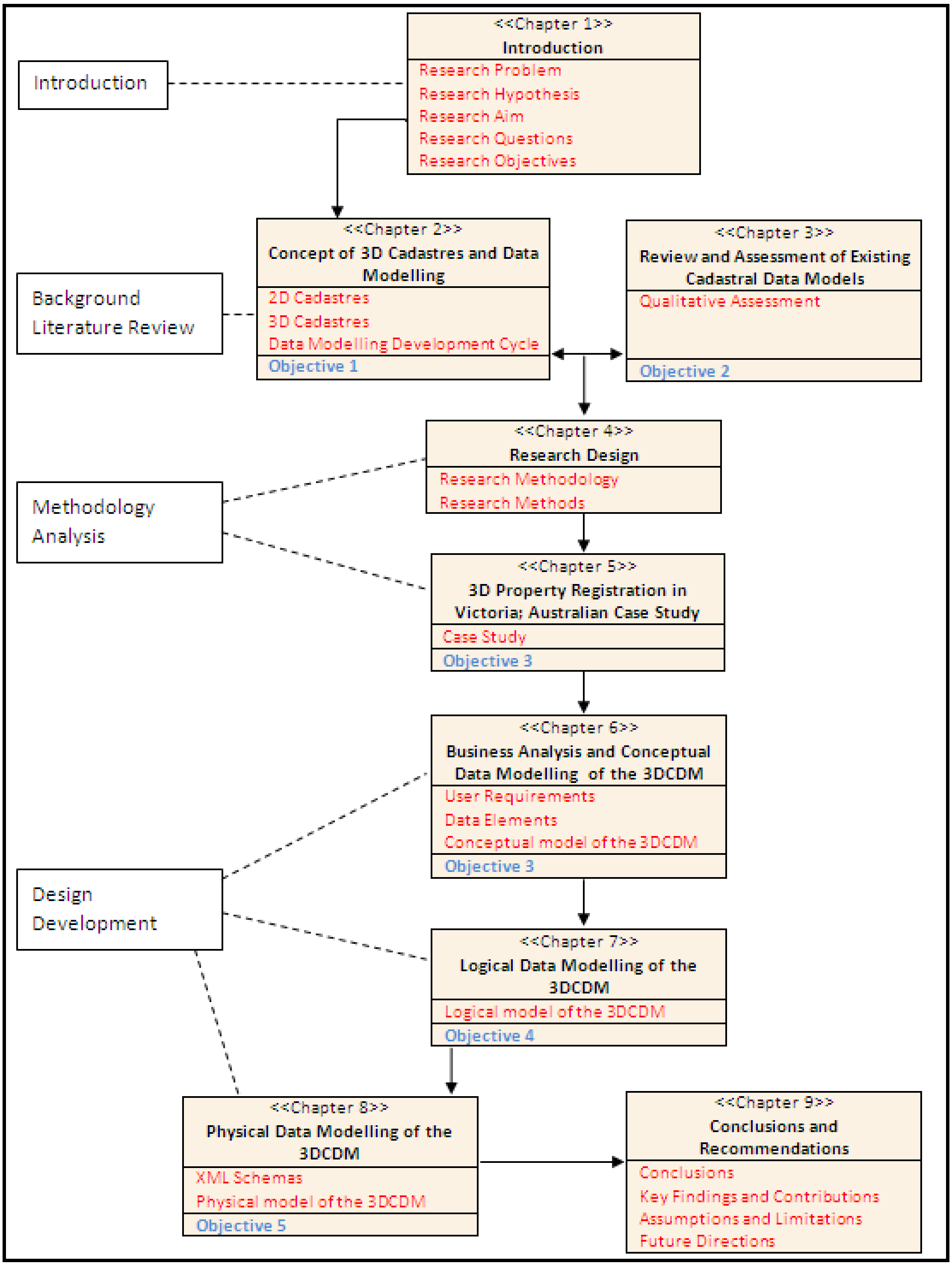


Figure 1.3: Structure of the thesis and its relationship to the research objectives

1.9 CHAPTER SUMMARY

This chapter has laid the foundations for the research and introduced the problem, question, aim and objectives of the research.

As a problem statement, it discussed how 3D developments of land put enormous pressure on current land administration systems that are equipped with the cadastres only able to maintain 2D spatial information. Further, that current land administration systems use 2D cadastral data models that do not incorporate legal and physical information, and they are not semantically enriched. Consequently, they are not sufficient enough to manage stratified land interests.

In considering the research problem, a key research question was formulated as ‘How can a data model be designed and developed to accommodate the requirements of 3D cadastres and interactions between all legal and physical objects?’

To respond to the problem statement and research question, five research objectives were considered: 1) to investigate concept, definition and requirements of 3D cadastres, 2) to investigate and assess current cadastral data models, 3) to identify the user requirements and main data elements of 3D cadastres, 4) to design and develop a 3D cadastral data model suitable for land administration systems, and 5) to develop a prototype to test the 3D cadastral data model using a case study.

Based on these five objectives, the research approach was designed in three phases: conceptual, design, and implementation phases, and the thesis structure has been outlined in nine chapters.

CHAPTER 2 – CONCEPTS OF 3D CADASTRES AND DATA MODELLING

2 CONCEPTS OF 3D CADASTRES AND DATA MODELLING

2.1 INTRODUCTION

This chapter aims to explain the concept and needs for 3D cadastres and 3D cadastral data modelling. Current cadastres (2D cadastres) and their problems regarding managing stratified rights, restrictions, and responsibilities are described. Then, concept, needs, and aspects of 3D cadastre are explained. This chapter ends with the importance of data modelling in the field of 3D cadastre.

2.2 2D CADASTRES

From the early stages of human settlement, land was undisputedly the primary source of wealth and power. To secure guarantee of land ownership, cadastres have been established and managed in different forms (Williamson, 1985). Their differences often depend upon local cultural heritage, physical geography, land use, technology, and etc. (Bełej et al., 2002).

Traditionally, cadastres were designed to assist in land taxation, real estate conveyancing, and land redistribution. Cadastres help to provide those involved in land transactions with relevant information and help to improve the efficiency of those transactions and security of tenure in general (Figure 2.1). They provide governments at all levels with complete inventories of land holdings for taxation and regulation. But today, the information is also increasingly used by both private and public sectors in land development, urban and rural planning, land management, city space management, and environmental monitoring (FIG, 1995).

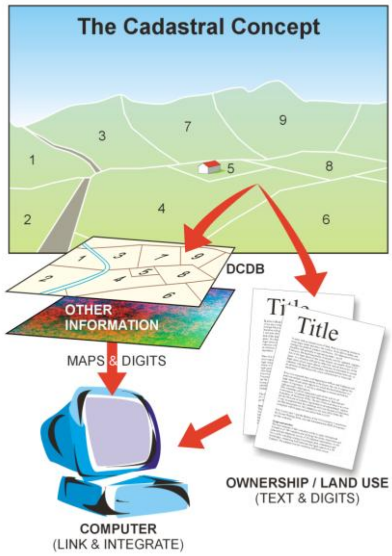


Figure 2.1: The Cadastral Concept (FIG, 1995)

Based on the FIG (International Federation of Surveyors) Statement on the Cadastre (FIG, 1995):

“A Cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g. valuation and equitable taxation), legal purposes (conveyancing), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection.”

It is concluded from this description that cadastres keep information about:

- land parcels (e.g. location, boundaries, coordinates, area, value)
- land tenure (e.g. property rights, restrictions, responsibilities, ownership, leases)
- land owners (e.g. interest holder information).

Land parcels are the basic spatial entity of the cadastres. Each parcel is given a unique code or parcel identifier. Therefore, other information such as buildings, utilities, land use, and demography (such as population statistics) can also be connected to land parcels through the unique parcel identifiers in GIS systems.

Land parcels are represented by cadastral maps, digital cadastral databases (DCDB), or survey plans. Due to historical, cultural and social differences, cadastral maps play very different roles in different jurisdictions ranging from being used in charting or index maps to being the legal determination of parcel boundaries (Williamson & Enemark, 1996).

Regardless of the purpose of cadastral maps, 2D representation methods (paper-based or CAD files) are common practice in most jurisdictions that represent geometrical information (boundary information) of land parcels and property details in cadastral maps or survey plans.

Cadastres that are equipped to show the geometry of parcels (2D) and to represent the legal status of these parcels (ownership information) are called 2D cadastres in this research project. Land parcel and 2D representation of land parcels are two main properties of 2D cadastres.

2D cadastres work well where the owner of a parcel is entitled to use the land in the parcel from the centre of the earth to the heavens (villa arrangements) according to law and building and urban planning regulations (Figure 2.2).

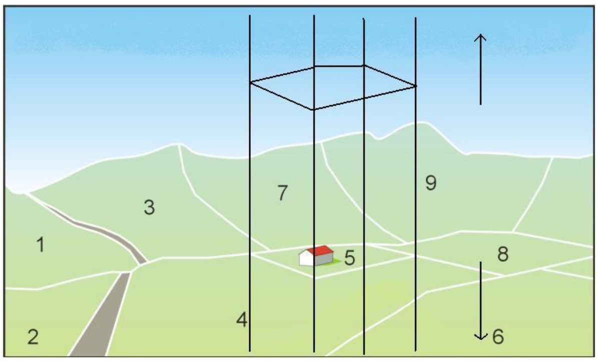


Figure 2.2: Owner of parcel and property no. 5 is entitled to use his land from the centre of the earth to the heavens.

One of the fundamental tools used to manage this arrangement is the limitation of building across parcel boundaries: the building stock is generally kept coherent with parcel boundaries. Historically, the theory of ownership and property rights was established before intensive land uses demanded a strata-titling system. When stratas were formalised into titles, it made sense to use them for both detached buildings and multi-storey developments.

In these cases, one parcel can be affected by a depth limitation (Figure 2.3) or a restriction can affect the height of any building that might be constructed (Figure 2.4). In this situation, the user might require a 3D representation of the ownership rights.

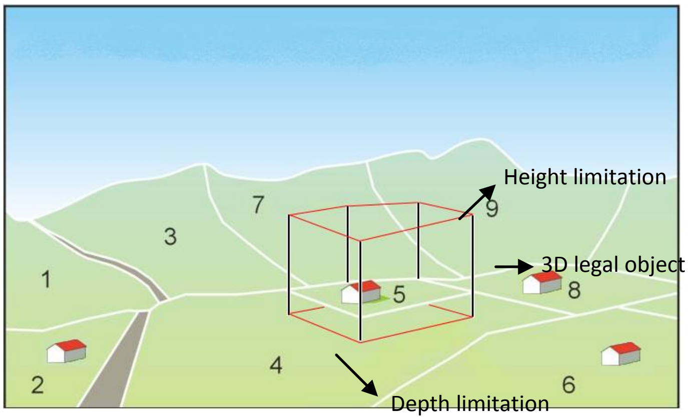


Figure 2.3: Land parcels are adequately represented by the 2D spatial extent of the boundaries of the land related to the rights, restrictions, and responsibilities.

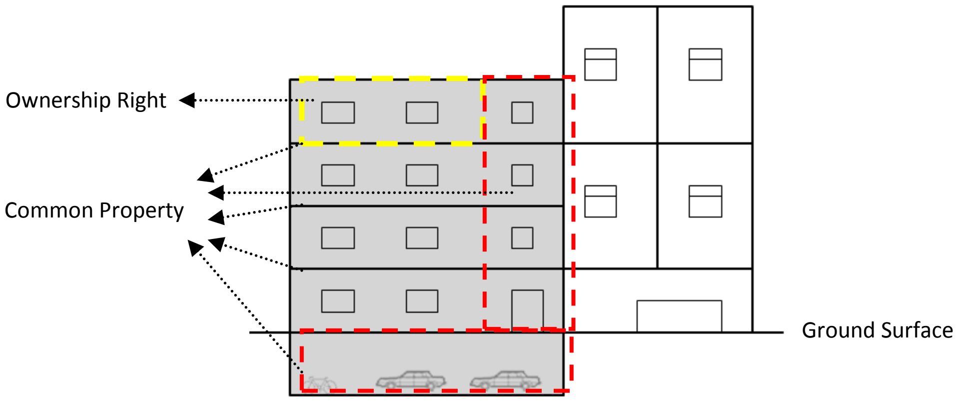


Figure 2.4: Multi occupancy residential or commercial buildings involve many strata units and common properties on one original parcel.

2D cadastres cannot effectively represent the complexities of reality. They are not able to manage and represent land ownership rights, restrictions and responsibilities in a 3D context.

The lack of an efficient and effective three-dimensional solution, limits the ability of the public to visualise and communicate 3D development and the ability of architects, engineers and developers to capitalise on the full potential of 3D title models. It also limits the ability of governments and developers to visualise multi-level developments resulting in increased costs and delays; and the ability of land registries to administer a title registration system that can accommodate these increasingly complex multi-level developments. For further discussion, problems of 2D cadastres are discussed in the next section.

2.3 PROBLEMS OF 2D CADASTRES

Obviously, the use of land involves multiple dimensions. However, cadastres focus on organising 2D land parcels. There are a number of reasons why cadastres do not accommodate 3D data. They are because of the lack of 3D data collection methods and equipment (i.e. lack of information in subdivision plans and architectural maps), and the limited 3D storage and representation technologies (3D DBMS, 3D topology, and 3D visualisation specifications). However, 3D developments under and above ground have changed the characteristics of cadastres.

Developments of apartments, high-rise buildings, tunnels, and utilities involve construction of above and below ground structures. These are of two distinct kinds.

First, development in a single parent parcel (Figure 2.4): In most systems that formally divide multi uses and multi occupancies in buildings into separate units capable of being uniquely owned and traded, the development occurs on a single parcel that is eventually subdivided to reflect the new configuration. These single original parcel developments are coherent in the cadastral framework, but for larger developments representation in 3D, rather than 2D, would help clarify the relativities and relationships among the units and common property.

Cadastral flexibility must encompass developments that produce separate and varied strata units for multi use and multi occupancy of residential and/or commercial buildings on one original parcel. The legal structure of these buildings is generally composed of individual lots, easements, and common property. Lots can include units, garages, storerooms and facilities that are owned by the lot owners. Common property includes parts of the land and buildings, below ground and airspace that are not within the defined private lots. These may include gardens, passages, walls, roofs, pathways, driveways, stairs, lifts, foyers and fences.

Figure 2.5 also illustrates the intersection of interests in one original parcel and the method of their legal representation in current 2D cadastres. In this example, residential apartment units are owned by individual home owners, and offices and commercial units are owned by legal entities established by businesses and organisations.

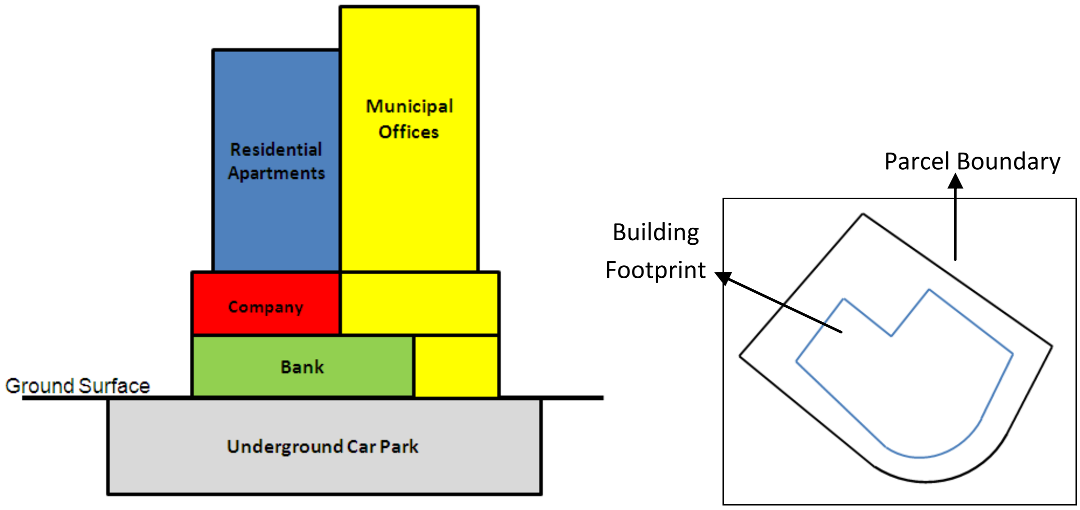


Figure 2.5: Multi occupancy residential/commercial buildings involve many strata units on one parcel and its representation in the current cadastral systems.

Second, developments that traverse existing parcels (Figure 2.5): Modern urban environments frequently require infrastructure that traverses existing parcels. This infrastructure might be small scale (such as underground car parks that require entry points accessible from roads that do not adjoin the parcel) or large scale (metro systems, highway tunnels, sewers, and so on) that affect below ground areas under many existing parcels. Legal management of developments with multi-parcel impact can be undertaken in many ways. The larger infrastructure developments usually attract specific enabling legislation that allows the government to retrieve or acquire the land so that developer/owner/operator can hold (leasehold or freehold) titles to the land as an underground strata area, that is with dimensions of height defining the upper and lower boundaries, and two dimensions of length and breadth showing the horizontal area.

In some cases, one development might involve using areas that are under or above the ground level of neighbouring or adjoining parcels (Figure 2.6). Legal systems that allow this will use a variety of strategies. A typical solution is the re-subdivision of the surface parcels to excise the areas above or below from their titles, and to create a new title with height and depth limitations defined by the contours and dimensions of the excised areas. Figure 2.7 illustrates the corresponding parcel-based representation of the legal situation that cannot be clearly represented in 2D configurations.

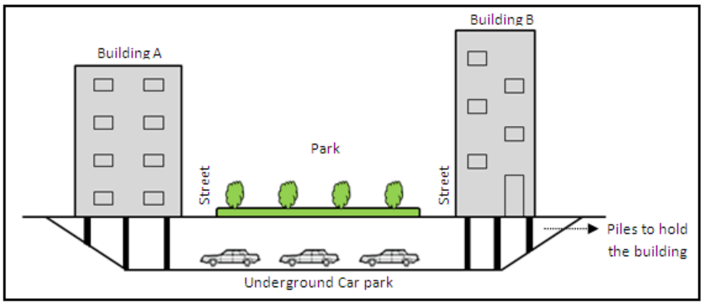


Figure 2.6: A car park and its related access paths crosses are built under existing buildings and public spaces.

Figure 2.7: Parcel-based cadastral map for the underground car park and crossing access, streets and adjoining buildings

These examples show how a cadastral system that defines only length and breadth of each parcel in a multi-dimensional world creates difficulties for interpretation of building interests.

The 2D description of parcel boundaries does not adequately explain the relationships among the varied parcels in buildings, especially constructions that involve below ground space. Representation of the arrangements by a series of ‘floor plans’ or ‘ground maps’ that rise up the floors in a building cannot adequately describe the arrangements of legal titles and the opportunities to use the physical structures. The 2D system serves well in simple buildings, and ground level villa unit developments, but management of modern cityscapes would benefit from a much more descriptive capacity in the land administration and titling systems.

Consequently, where there is multiple use of space with stratified property rights in land, 2D cadastres are unable to adequately reflect the spatial information about those rights in the third dimension. There is a need for 3D cadastres to manage and represent stratified land rights, restrictions, and responsibilities in 3D.

2.4 NEEDS FOR 3D CADASTRES

The world’s population is being urbanised: the majority of people now live in towns and cities (UN-FPA 2008). Australia, for example, is also experiencing this urban migration. The ABS projects Australia’s population to almost double over the next 47 years increasing from 22 million to up to potentially 42.5 million by 2056 (UN-FPA, 2008).

The majority of these people will live in cities. These increasingly urbanised populations will predominantly live in multi-level, multi-purpose, highly engineered, high-rise developments. Rapidly expanding vertical cities and their populations will experience a range of new environmental, social and economic challenges (Hillman, 1983).

It is essential the infrastructure is in place to model and manage these new 3D environments (UN-FPA, 2008). This infrastructure should include verified, authorised, repeatable, engineered information about 3D environments, not just the surveyed external boundaries of structures and parcel boundaries that appear in two-dimensional drawings.

The problem of creating efficient and accurate spatial representation of people's rights, restrictions and responsibilities in buildings and infrastructure above and below ground is shared by all cities of the world, irrespective of the level of development (Figure 2.8).

Figure 2.8: Busy high-rise megacity like Hong Kong, China (Williamson et al. 2010)

The third dimension of height in land information systems facilitates subdivision of space into strata legal property objects capable of being owned by different entities and used for unrelated purposes while facilitating management of the entirety. This creates separate legal property objects above or under the original property parcel or unit. The most typical objects located above the surface are apartments or buildings registered as separate property (Rajabifard et al., 2012).

Increasingly, construction below or above the surface, such as tunnels and platforms used as foundations for buildings and so on (Figure 2.9), are also treated as 3D objects in a land subdivision process (Stoter, 2004). In some jurisdictions, networks such as telecommunication lines, water pipes and gas supply grids, and communication systems may also be registered, either within the land registry (as has been proposed in The Netherlands) or in a separate register (as for high-voltage power lines in Norway). 3D cadastres can also include interests related to trees, vegetation, minerals, hydrocarbons, as well as water (Bennett et al., 2005; Rajabifard et al., 2006; Kalantari et al., 2008).

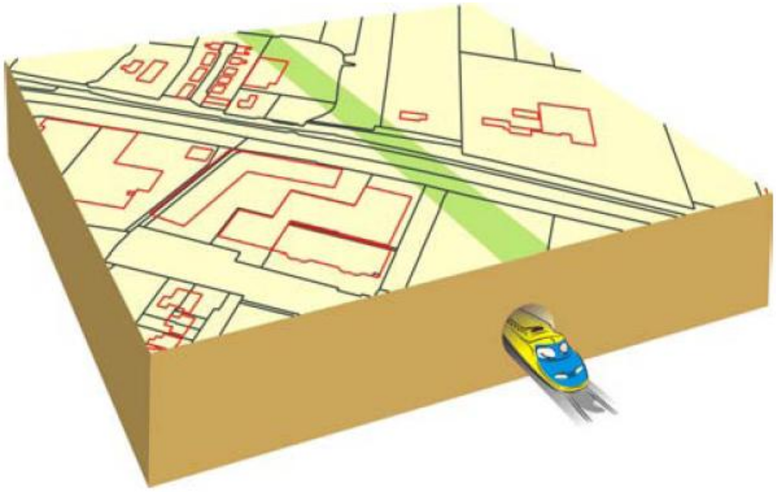


Figure 2.9: Construction below or above the surface (Stoter, 2004)

Factors that highlight the need for 3D cadastres include an increase in property values, escalating numbers of overlapping transport routes, proliferation of utility infrastructure including cables and pipelines, management of complex natural environments alongside built infrastructure, and emergence of useful 3D technologies for design, planning and management.

Also, in current land information system data models, the third dimension is usually inadequately modelled as a 3D tag linked to the parcel record (Stoter & Oosterom, 2003). The increasing complexity of modern cities demands that modern land administration systems include heights and capacity to visualise inter-relationships between structures and uses for sustainable management (Wallace & Williamson, 2004).

The land administration sectors in Australia recognise the importance of having land information in 3D, especially in cadastres. Since February 2012, the Centre for Spatial Data Infrastructures and Land Administration (CSDILA) at the University of Melbourne have started to investigate about the different aspects of the 3D cadastre. The involvement of Australian Research Council (ARC) and industry partners in the research project illustrates the importance of land and property information in 3D which will assist the implementation of the 3D cadastre by focusing on the development of partnerships as a means of solving issues in relation to the increasing number of interests in land. This will build the research capacity in Australia to further investigate different technical, policy and institutional aspects of 3D cadastres.

The project partners include Department of Sustainability and Environment (DSE), Land Victoria, Intergovernmental Committee on Surveying and Mapping Australia (ICSM), Land and Property Information NSW (LPI), VEKTA, Alexander Symonds, PSMA, Australia, Strata Communities Victoria (OCV), Fender Katsalidis Architects (FKA).

Australia's Intergovernmental Committee on Surveying and Mapping (ICSM), which includes all land administration authorities in Australia, in its 'Strategic Pathways and Milestones 2008-2010' (ICSM, 2008b), identified the 3D cadastre as an emerging trend and supported research into 3D cadastre development.

Accordingly two land administration authorities (Land Victoria and LPI) and a national coordination body (ICSM) have committed significant resources to this project. In addition, three key private organisations active in land subdivision and construction in multi-level developments have given their support in this project with a significant resource commitment (Rajabifard et al., 2012).

Overall, the basic needs for the 3D cadastre are to:

- explicitly register 3D space to which 3D rights apply
- have good accessibility to the legal status of 3D properties, including 3D spatial information as well as public law restrictions
- identify significant land and buildings subject to flooding (especially those in CBD high value and high impact areas)
- identify parcels that cross other parcels
- support "high value infrastructure" that should be 3D and "height enabled": CityLink, Melbourne, Australia (http://www.citylink.com.au/)

- support new style high-rise and low-rise buildings and developments: Queen Victoria Building, Melbourne, Australia (http://www.qvb.com.au/)

- support infrastructure beyond land parcels: infrastructure assets and their position require heights. For example, above ground transmission and electrical wires should be mapped in the cadastral maps.

After identifying the basic needs for 3D cadastres, the concept of 3D cadastre including the definition and benefits of 3D cadastre is described in the next section.

2.5 3D CADASTRES

3D cadastres manage and represent real property ownership rights, restrictions, and responsibilities in 3D. They are used when there are stratified rights on, above or under a particular extend of land. In this research, 3D cadastres are referred to as ***digital 3D cadastres***.

3D cadastres digitally represent real property ownership rights, restrictions, and responsibilities (legal models) and their physical counterparts such as buildings, utilities, on, above or under the ground surface. They are equipped with 3D data storage, 3D visualisation, and 3D spatial analysis functions.

They facilitate management of property rights; registration of strata plans; and reduction of boundary disputes between owners and Owner Corporations. They also enable a wide variety of applications, which in turn create a demand for detailed and integrated 3D legal and physical objects.

3D cadastres provide important information for different applications such as city space management and land and property management in 3D (Rajabifard et al., 2012). First, they represent the spatial extent of ownership boundaries in 3D where layered ownerships exist. Second, they facilitate registration of strata developments. Third, they support land development processes including the issuing of permit plans in dense urban areas especially for huge developments such as bridges and tunnels that cross above or under other developments. Fourth, they provide reliable information for governors and decision makers. Last but not least, they are utilised as a basic layer to integrate with other information layers such as 3D city models (CityGML), Building Information Model (BIM), transportation, utility networks, land use, and employment to services for different applications.

Definition of 3D cadastre in this research is explained in the next section to further clarify the concept of 3D cadastres.

2.6 DEFINITION OF 3D CADASTRE

Since 3D cadastre is a vast subject, there are different ideas about 3D cadastre. Hence, some existing 3D cadastre definitions will be mentioned from various researchers' points of view before finally defining the 3D cadastre in this research.

- A 3D cadastre is a cadastre which registers and gives insight into rights and restrictions not only on parcels but also on 3D property units (Stoter, 2004).

- 3D Cadastre provides information beyond the typical planar data and can be use to ensure registered rights below & above the land surface. Land use of underground and above-ground parcels, can be thus described, analysed and optimally developed and exploited (Papaefthymiou et al., 2004).

- The 3D cadastre system will manage the 3D spatial data in strata in the same way the 2D-GIS system manages the 2D spatial data currently. This task can be separated into two parts; the first being 3D cadastral data spatial analysis of 3D parcels and 3D objects, and the second is 3D digital visualisation. 3D registration deals with maintaining spatial and non-spatial information on 3D objects, which are core topics of 3D GIS (Jarroush & Even-Tzur, 2004).

- A modern cadastral system should always reflect the existing status of all property rights, including private and public properties. This provides better means for a rationalized management of the built environment, including regulations of legality of use or economic applications (Dimopoulou et al., 2006).

The variation between these definitions is the result of different attitudes towards cadastres. However, most of the definitions purely reflect the legal portion (registration) of 3D cadastres and neglect integration of physical counterpart. Therefore, 3D cadastre is defined in this research as:

- 3D cadastre is a tool in a land administration system to digitally manage and represent stratified rights, restrictions, and responsibilities (legal models) and their corresponding physical models such as buildings, utilities, on, above or under the ground surface in 3D. A 3D Cadastre has the capability to capture, store, edit, query, analyse and visualise multi-complex properties and frameworks within a documented set of standards.

2.7 BENEFITS OF 3D CADASTRE

The ability to maintain 3D information relating to property interests and make it available through the land administration systems will provide important benefits at government levels. Its greater benefits lie at the public level where it will assist management of the economy of 3D land development, security of tenure and community engagement (Rajabifard et al., 2012).

Building data show a trend of strong growth in approvals for residential dwellings in inner city areas of many Australian cities (ABS, 2009). Implementation of a 3D land and property information system potentially provides significant long-term benefits and savings for the community in the land development processes as more than 50 percent of land development proposals involve height allocations.

A clear understanding of 3D developments through computer visualisation will help reduce misunderstandings and disputes between developers, owners and managers, and the public. At the same time this will improve the ability of authorities, such as local government and utility companies, to effectively plan large multi-unit developments such as shopping centres, bridges and tunnels.

Access to comprehensive and integrated land and property information in 3D will modernise processes of land and property development in Australian cities and prevent confusion, administrative friction and disputes during decision making.

An aggregated database of different disciplinary datasets, such as land valuation, land use, utility management, property tenure, lease and occupancy in a 3D environment will provide municipalities and utility companies with the seamless information and tools to facilitate comprehensive and efficient engagement with the community.

Currently, in Australia, principles for recording overlapping interests in land are fragmented and not available in a cohesive and integrated way. Historically 2D systems managed interests in land and property effectively. These flat systems cannot manage the increasing number of 3D property rights, restrictions and responsibilities in Australia.

The fast growing populations and pressure to integrate facilities on, above and under the surface of cities and natural environments demand the introduction of a holistic approach to managing the third dimension in Australia. The availability of 3D spatial land information systems will enable governments to effectively respond to the fast growth of Australia's cities.

Benefits of 3D cadastres and their potential needs persuade scientists and land administration authorities to develop and implement the 3D cadastre. Different aspects should be considered to successfully develop a 3D cadastre. These aspects are explained in the next chapter.

2.8 ASPECTS OF 3D CADASTRE

Establishment of 3D properties and multiple ownership in a single building are not allowed in all jurisdictions (Stoter & Oosterom, 2006). For example, establishment of 3D construction properties was not allowed in Norway or a division of ownership was not possible in the third dimension in Sweden (Stoter & Oosterom, 2006). In Victoria, Australia, current legislation allows owners and developers to register 3D properties by the introduction of subsequent and complementary Acts such as the Transfer of Land Act (Stratum Act) 1960, Strata Title Act 1967, Cluster Titles Act 1974, and Subdivision Act 1988 (Libbis & Leshinsky, 2008). It is obvious that the legal aspects are the fundamental part of the 3D cadastral systems, which secure 3D properties and support the demands for multiple ownerships of land and buildings.

Legal aspects are not the only concern in the 3D cadastre. Institutional aspects play a significant role by regulating property rights, providing guidelines and standards for 3D data acquisition, and defining tasks and responsibilities of the private and public sectors (Molen, 2003; Ho & Rajabifard, 2012). Institutional aspects can provide a road map to facilitate the accommodation of a 3D cadastre.

Figure 2.10 suggests that a 3D cadastre should be considered in three main aspects: legal (which supports the register of 3D properties), institutional (which established relationships between involved parties), and technical (which provides platforms to realise the 3D cadastre). These aspects should be considered in 3D cadastre developments for each jurisdiction (Aien et al., 2011b).

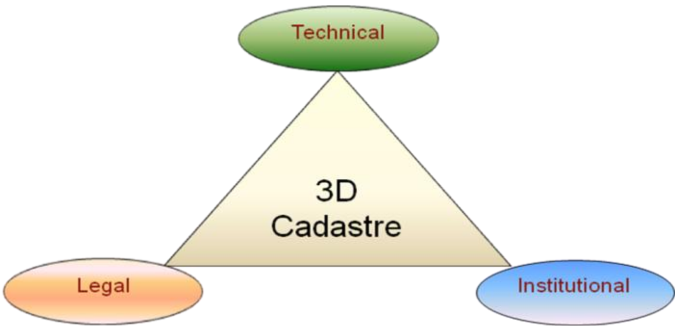


Figure 2.10: Relationship between different aspects of 3D cadastre

2.8.1 LEGAL ASPECTS OF 3D CADASTRES

3D property owners such as the owner of an apartment unit are entitled to use a specific 3D space. These 3D spaces are usually located on top of each other within one land parcel or sometimes extending over a number of land parcels. In most jurisdictions, owners of 3D properties share implicit rights in the common areas that are mostly managed by service companies and Owners Corporation. 3D property legislations, if they exist, do not support a full 3D property representation in some jurisdictions. For example, establishment of 3D construction properties were not allowed in Norway or a division of ownership was not possible in the third dimension in Sweden (Stoter & Oosterom, 2006). To overcome this problem, legal systems in some countries, have to develop to support registration and representation of 3D properties.

For example, the property legislation was developed in Victoria (Australia) over a long period of time to meet the demands for multiple ownerships of land and buildings because financial institutions would not accept such a 3D property as security for funding. Until the Subdivision Act 1988, different Acts and regulations were introduced to legislate for owning and securing 3D properties (Figure 2.10), but all these have evolved to meet the needs of developers, owners, mortgagees and planners of 3D properties (Libbis, 2006; Paulsson, 2007).

In Victoria, the basic subdivision of land used to be carried out under the provisions of the now repealed Local Government Act 1958, and then were registered at the Land Registry under provisions of the Transfer of Land Act 1958 (Figure 2.11). This type of subdivision was inflexible in that it only allowed for the subdivision of land along defined horizontal boundaries on the ground.

The Transfer of Land (Stratum Estate) Act 1960 provided a legislative framework for separate ownership of flats or other units. It enables titles to be issued for each owner and a title for common areas, which are owned by a service company.

In the Strata Title Act 1967, separate titles were available for each unit. The owners corporation came into existence instead of the service company and is registered in the Land Registry with its details, rules, rights and responsibilities. Each owner is automatically a member of the owners corporation. Thus, dealing with the strata title was considerably less complex than stratum title.

The Cluster Titles Act attempted to resolve the problem of staging and the progressive creation of common property, as well as to provide for pre-selling and to overcome constraints that applied to site requirements and the sharing of facilities. The Act promised future subdivisions that preserved special site features, such as trees or streams, and the provision of special interest developments, such as tennis courts or stables and horse tracks, but these expectations were not fulfilled.

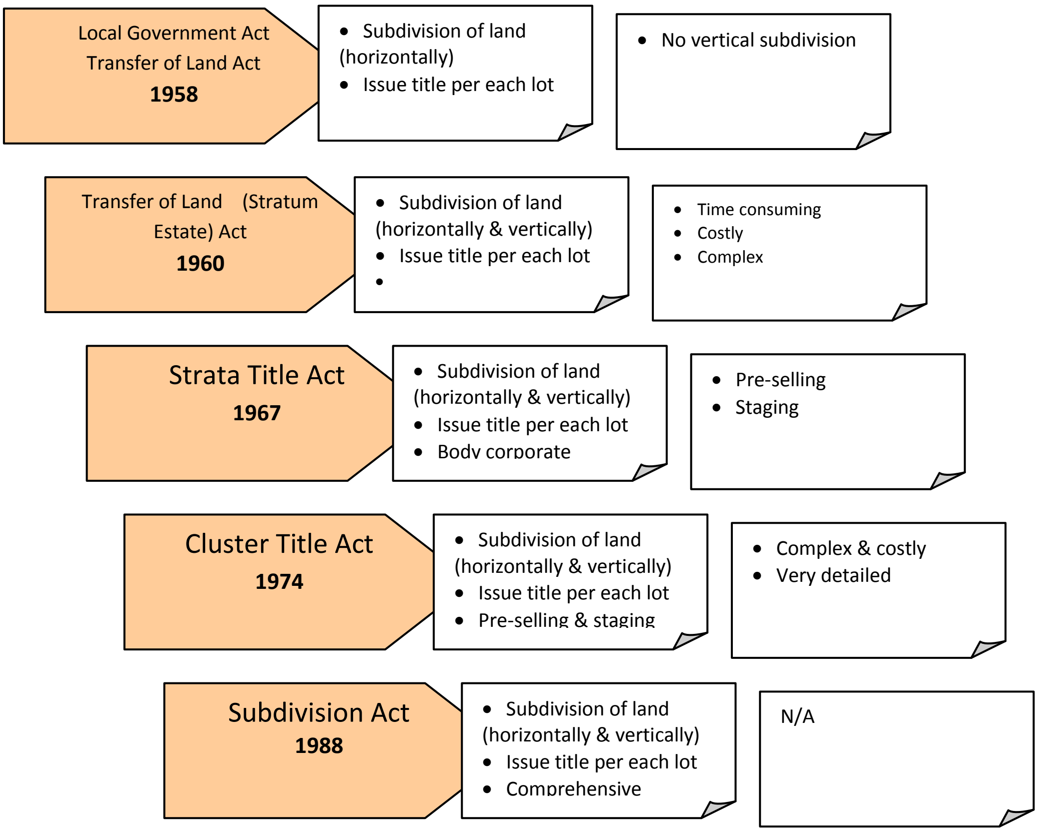


Figure 2.11: 3D property legislation (Subdivision Acts) in Victoria for Freehold lands

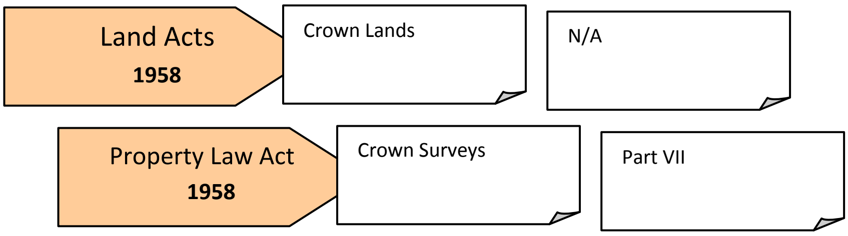


Figure 2.12: Subdivision Act in Victoria for Crown lands

The subdivision system before the Subdivision Act 1988 was regarded as complex, costly and time consuming. The objectives of the Subdivision Act were to introduce a uniform process for subdivision approvals that are part of the planning system, a uniform style of title for property in Victoria; a system that is sufficiently flexible to allow for changes to be implemented from time to time; a system which has the municipal council as the central body responsible for the co-ordination of planning; building, traffic and drainage control, and a simplified Act, which can more readily be understood by interested users and laymen, such as developers and members of the bodies corporate. The Land Act 1958 and the Property Law Act 1958 (Figure 2.12) were developed to subdivide Crown lands (Libbis, 2006; Paulsson, 2007).

Victoria’s current legislation allows owners and developers to register 3D properties; however, depicting 3D rights, restrictions and responsibilities is paper based, complex, and difficult to be understood by the public.

2.8.2 INSTITUTIONAL ASPECTS OF 3D CADASTRES

Legal aspects lay the ground work for land administration, but cadastres are only meaningful if they operate within an institutional context, providing regulations for defining property rights, defining mechanisms for acquisition, etc., and defining tasks and responsibilities of the public administration empowered to register. This is equally true for 3D cadastres. Without defining the third dimension in property rights regimes, 3D cadastres are meaningless (Molen, 2003).

As shown in Figure 2.13, there should be a close and consistent relationship between public and private sectors to share knowledge and to reach a common viewpoint on the concepts and principles for the development of 3D cadastres.

Institutional aspects can be divided into different categories. Firstly, administrative institutions that execute and protect the regulations set by the legislations. These might include surveyor-general, registration body for cadastral surveyors, land registry, local government, association of developers, and association of Owners Corporation.

The second category are conceptual institutions that provide a unified of 3D concepts such as, apartments, 3D ownership, 3D property, multi-storey buildings, high-rise buildings, complex buildings and so on.

Institutions in the area of 3D cadastres can be seen as institutions in support of organisational reform. It is essential to analyse what reforms are required from an organisational perspective to support implementation of 3D cadastre (Ho & Rajabifard, 2012).

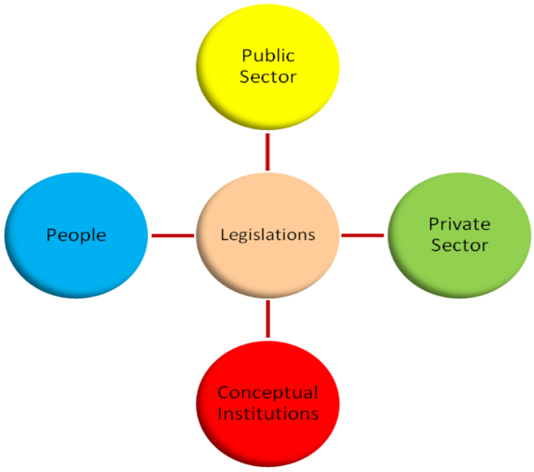


Figure 2.13: Relationship between organisations

In addition, legal and technical aspects can drive institutional aspects. For example, the Department of Sustainability and Environment (DSE) and the Department of Planning and Community Development (DPCD) in Victoria are two separate departments with different responsibilities. DSE facilitates the land registration process and acknowledges subdivision plans and issues titles. DPCD assesses and issues planning approval for applicants. However, the SPEAR project created a platform for the two departments to work with one system. SPEAR (Streamlined Planning through Electronic Applications and Referrals) project allows subdivision and planning approval applications to be compiled, lodged, managed, referred, approved and tracked online anytime (http://www.spear.land.vic.gov.au/spear/). Therefore, it can be seen that technology and technical aspects drive institutional aspects as well.

2.8.3 TECHNICAL ASPECTS OF 3D CADASTRES

Technology in 3D cadastre is the use and knowledge of tools, models and methods to develop 3D cadastre. Progress in technology increases the efficiency of cadastres.

Functionality of cadastres develops in accordance to progress in computers and data capturing methods (Table 2.1).

Table 2.1: 3D cadastre development

Time	Available Technology	Aims of Cadastre	Possibility of 3D Representation
Before 1980s	Paper	Registration, Fiscal, 2D Visualisation	N/A
1980s	CAD	Registration, Fiscal, 2D Visualisation	N/A
1990s	CAD, GIS	Registration, Fiscal, 2D Visualisation, 2D Vector-based Analysis	N/A
2000s	CAD, GIS, 3D Raster-based Tools	Registration, Fiscal, 3D Raster-based Visualisation, 2D Vector-based Analysis	Yes
2010	Augmented reality Virtual reality	Registration, Fiscal, 3D Vector-based Visualisation, 2D Vector-based Analysis	Yes
Future	3D (CAD, GIS), 3D DBMS 3D Vector-based	3D Registration, Fiscal, 3D Visualisation, 3D Vector-based Analysis	Yes

While cadastres were paper based, they were used for a limited applications such as land inventory and taxation purposes (Ting & Williamson, 1999). Nowadays, GIS and other spatial analytical systems put more applications on cadastres and it is possible to analyse and query cadastral data. Although all efforts on cadastral system were previously 2D, new initiatives such as Google Earth, Trimble SketchUp, Autodesk's AutoCAD Map 3D, Bentely's City GIS, Esri's ArcGIS, CityGML, and Building Information Models (BIM) are promoting researchers to consider the practical possibilities of 3D cadastre. Inevitably, 3D cadastre will be achieved by developing 3D

CAD, 3D GIS, and 3D DBMS, which will provide possibility of drawing, updating, analysing and visualising 3D cadastral objects and 3D spatial ownership of land rights, restrictions and responsibilities that is completely independent of 2D land parcels with a geometrical and topological structure in both raster and vector based format.

In addition, it should be noted that, current 2D cadastral data such as boundaries of land parcels is essential and is expensive to acquire in both time and money. Therefore, it is important to utilise current cadastral data in 3D cadastre developments.

Technical aspects of 3D cadastre vary by content and can be categorised into different subjects based on their objectives (Figure 2.14):

- 3D data capturing: researching on what types of 3D cadastral objects need to be collected (buildings, pipelines, tunnels, etc.) and what methods of 3D data capturing can be used to capture 3D data (land surveying, aerial photogrammetry, laser scanning, etc.). Integration of different 3D data capturing methods is one solution in this research area, while cross-sections are being used to determine vertical aspects of 3D cadastral objects.

- 3D data representation: visualising 3D cadastral objects, 3D analyses and 2.5D earth surface in vector and raster formats. 3D GIS and CAD systems can provide this opportunity. 2D paper-based plans are being used to represent 3D data in most cadastral systems.

- Cadastral updating: updating cadastral objects in DCDB. Geometry and topology of 3D cadastral objects are complex and they need to be maintained in a 3D DBMS. Currently 2D DBMSs are being used for 3D cadastre.

- 3D data modelling: developing data models to identify 3D objects and their relationships. 3D cadastral data modelling will enable the capture, manipulation, analysis and visualisation of 3D land rights, restrictions and responsibilities. Most of the existing cadastral data models are 2D, such as the ePlan data model

(ICSM, 2009) which is restricted in its cover to a few 3D objects such as volumetric lots.

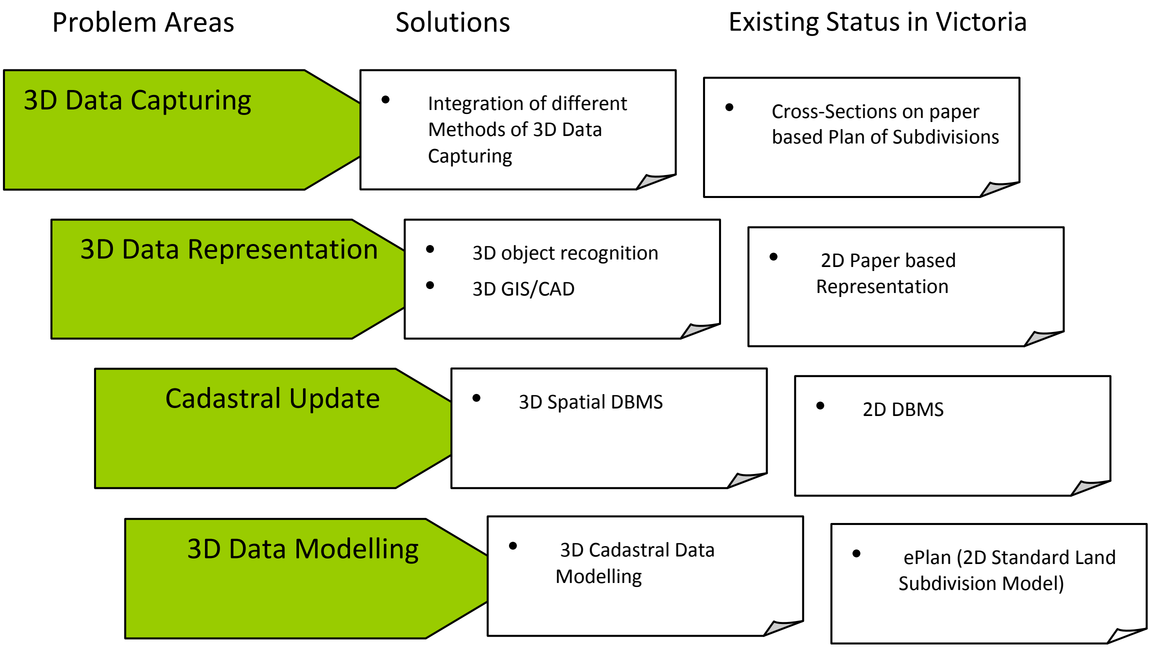


Figure 2.14: Technical problem areas in 3D cadastre

2.9 3D CADASTRE TREE DIAGRAM

Legal, institutional, and technical aspects of 3D cadastre are essential for successful implementation of a 3D cadastre. Figure 2.15 (3D cadastre tree diagram) describes how these three aspects supply a 3D cadastre to serve for different applications. This diagram illustrates the requirements of 3D cadastres to support different applications such as urban planning, registration of 3D RRRs, 3D visualisation, dispute reduction, securing and financing 3D properties, increase property value, and infrastructure management are all examples of 3D cadastre applications. Legal aspects (Legal and Land Policies) play a fundamental role and facilitate the establishment of the 3D cadastre. A 3D cadastre also needs technical support such as 3D data capturing, manipulating and visualisation technologies to increase the efficiency of 3D cadastres.

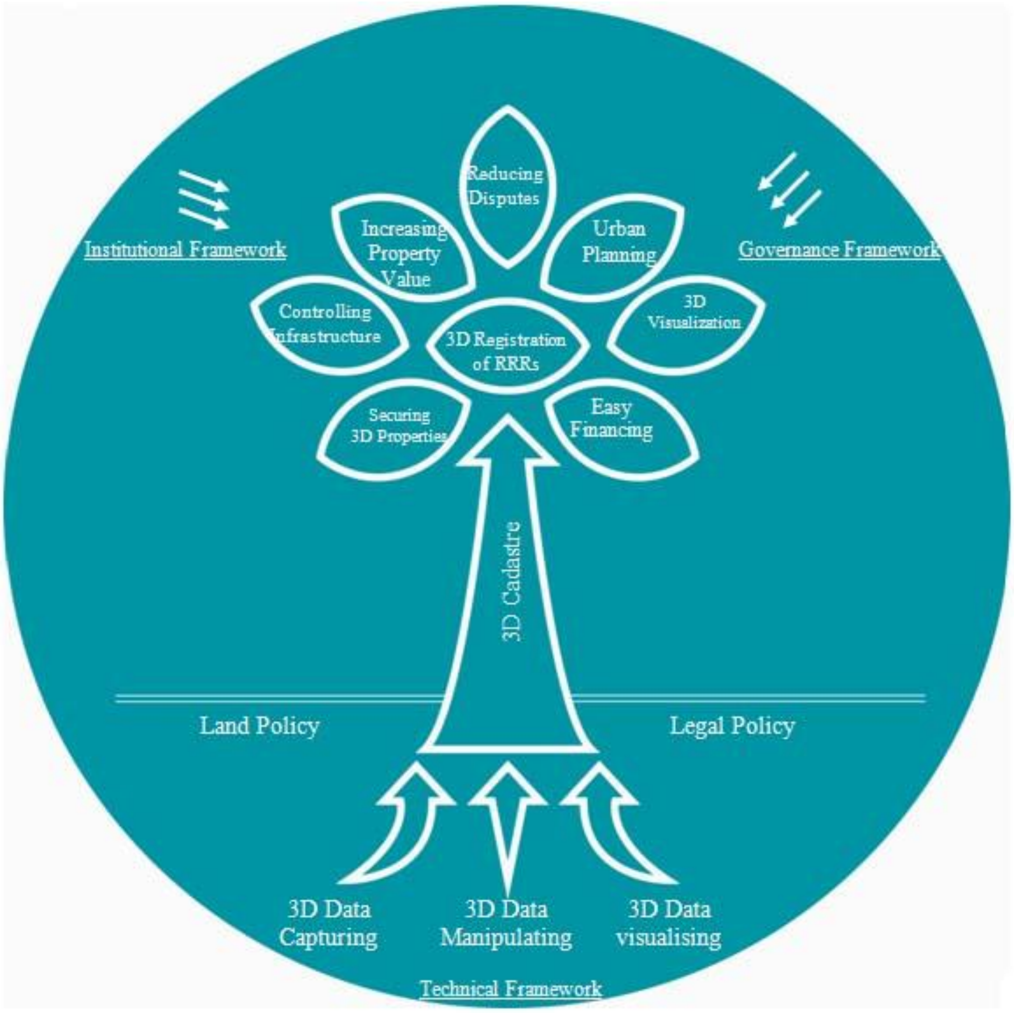


Figure 2.15: 3D cadastre tree diagram

The aspects of 3D cadastre represent the basic requirements for any jurisdiction developing a 3D cadastre. These are somewhat generic because confused and conflicting expectations for 3D cadastre ensure ambiguity. As such, determining the scope of 3D cadastres is another step that should be considered before developing a 3D cadastral data model.

2.10 SCOPE OF 3D CADASTRE

The 3D cadastre concept emerged in the early 2000s. An initial workshop was held in 2001; a second followed in 2011and third in 2012. In the interim, numerous theoretical and practical developments emerged. However, as yet there is no true 3D cadastre implemented anywhere in the world (Oosterom et al., 2011).

There are several reasons why 3D cadastres have not been successfully implemented: legal, institutional, and technical aspects all play a role. Specific reasons include the lack of:

- legal support and mandate to register 3D properties
- specified guidelines and standards for surveyors to capture required 3D data, and a lack of data formats to integrate and exchange 3D data
- business cases and cost-effective analysis for implementing 3D cadastres (conversion or integration of existing systems to 3D, capture of new data)
- available technologies for storing, manipulating, and visualising 3D objects.

However, a lack of a clear scope for 3D cadastres is one of the main obstacles to advancing implementation. 3D cadastres appear to have numerous demands and unanswered questions:

- What are the application areas of 3D cadastres? Should 3D cadastres only be implemented in the most dense urban areas (e.g. city centres), in entire urban areas including all above and underground infrastructures, or even in rural areas, including underground pipelines and mines?
- What is the purpose of 3D cadastres? Should 3D cadastre serve fiscal and legal purposes, or it should be a multipurpose cadastre?
- What objects should be registered in 3D cadastres? Should only legal spaces (RRRs and public law restrictions) be registered, or should physical objects such as buildings, units, and pipelines be registered in 3D cadastre?
- What is the level of detail required of a 3D cadastre? Should 3D cadastres be multi-scale systems and include as much as detailed information as possible, or should they only represent empty volumes?

There are other scoping options beyond these, and they should be identified prior to implementation of 3D cadastres. Without a clear scope for 3D cadastres, developers must contend with confused and conflicting expectations. This makes the implementation of the 3D cadastre difficult.

The scope of 3D cadastres ideally should be defined in legal and institutional systems. Pending these formalities, developing a data model for 3D cadastres is a useful method to clarify the scope of a 3D cadastre. A 3D cadastral data model provides:

- exploration of the different parts of 3D cadastres (objects, elements, attributes, and constraints) and how they are arranged
- organisation and provision of documents and practical guidelines for land surveying professionals
- simplification of the process of implementing 3D cadastres
- promotion of standards and a common language within the land administration user communities
- foundation of a 3D cadastre database
- facilitation of the exchange of data and the integration of similar datasets, and ease data sharing and interoperability
- understanding data requirements of involved parties.

Overall, a 3D cadastral data model can provide a framework and template to define and explore the 3D cadastre by identifying 3D cadastre elements (classes and attributes) and their arrangements (associations, cardinality, and constrains) and can therefore facilitate its implementation.

Since the aim of this research is to develop a 3D cadastral data model, the concept and development of data modelling process are described in the next section.

2.11 DATA MODELLING

Data models are normally developed according to specific purposes. Data modellers decide how to model the data to fit the type of problems they are trying to solve. Since land administration requirements differ among the different jurisdictions, various cadastral data models have been developed around the world (Aien et al., 2011a).

Data modelling development is often an iterative and cyclical process used to create a perfect model of the real world. The data modelling development cycle approach is used in this research to develop a new 3D cadastral data model (3DCDM).

The data modelling development cycle (Figure 2.16) usually starts from mapping the concepts and their relationships of the real world to a conceptual model. This model includes all major entities and relationships and does not contain much detailed levels of information about attributes. The conceptual data model is created by gathering requirements from various sources such as business documents, discussion with technical teams, business analysts, management experts and end users. The conceptual data model is then translated into a logical data model, which documents structures of the data that can be implemented in a database. The last step in data modelling involves transferring the logical data model to a physical data model that organises the data into tables (Elmasri & Navathe, 2011).

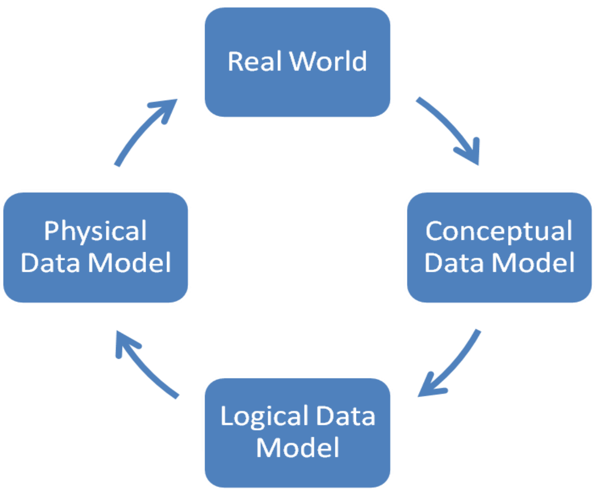


Figure 2.16: Data modelling development cycle

According to the modelling cycle (Teorey et al., 2011), a 3D cadastral data modelling cycle and database development consist of five steps:

- Step 1: gathering requirements of 3D cadastre (Business Analysis)
- Step 2: developing a conceptual data model of 3D cadastre
- Step 3: developing a logical data model of 3D cadastre
- Step 4: developing a physical data model of 3D cadastre
- Step 5: designing a 3D cadastral database.

The research strategy in this dissertation will focus on the first four steps, which concentrates on the conceptual, logical, and physical models of the data modelling development process. This enables the scope of 3D cadastres to be clarified by modelling the requirements of stakeholders who are interested in 3D cadastres and defining the concepts of the 3D cadastre through interviews and publication reviews. The logical data model (the 3DCDM model) is then presented based on the requirements.

2.12 CHAPTER SUMMARY

Current cadastral systems are two dimensional (2D cadastre), that is, geometric and descriptive information is based on 2D land parcels, even if stratified rights, restrictions, and responsibilities (RRRs) are situated above or under the land parcels. They are successfully used for fiscal and legal purposes, and also utilised as a base layer in other applications such as planning, city space management, and disaster management.

The advent of 3D developments such as apartments, high-rise buildings, and complex infrastructures (both above and below ground), has resulted in land administrators attempting to incorporate the third dimension into cadastral systems. The aim is to better enable effective management and registration of 3D land rights, restrictions, and responsibilities (RRRs).

3D cadastres will assist in managing the effects of 3D developments on a particular extent of land. They should be capable of storing, manipulating, querying, analysis, updating, and visualising 3D land rights, restrictions and responsibilities.

For development purposes, 3D cadastres should be considered in three main aspects for each jurisdiction. They are legal, institutional, and technical. Legal systems would support registration and representation of 3D properties to meet the demands for multiple ownerships of land and buildings. Institutional aspects would provide regulations for defining 3D property rights, mechanisms for acquisition 3D data, and the tasks and responsibilities of the public and private sectors. Technical aspects such as 3D data capture, visualisation, updating and modelling would facilitate the development and implementation of 3D cadastre.

3D cadastral data modelling is an essential step for developing a successful 3D cadastre. It is a useful method to clarify the scope of a 3D cadastre. A 3D cadastral data model can provide a framework and template to define and explore the 3D cadastre and to facilitate its implementation. It assists in identifying what objects should be considered in a 3D cadastre.

This chapter discussed why 2D cadastres are not capable of managing stratified land rights, restrictions, and responsibilities. The needs for a 3D cadastre were identified. The aspects of a 3D cadastre (legal, institutional, and technical) were described in detail to consider for implementation purpose. It was summarised why 3D cadastres have not been successfully implemented yet. Lack of a clear scope for 3D cadastres was identified as one of the main obstacles to advance implementation. Also, the importance of the 3D cadastral data modelling was described as one of the useful methods to clarify the scope of a 3D cadastre by identifying 3D cadastre elements (classes and attributes) and their arrangements (associations, cardinality, and constrains). Finally, data modelling development cycle and the strategy of this research to accommodate this method of data modelling were explained.

Since land administration requirements differ among the different jurisdictions, various cadastral data models have been developed around the world. The following chapter describes the qualitative assessment results of the current cadastral data models to identify issues, obstacles and complications as well as successful experiences and best practices in accommodating the requirements of 3D cadastres. This assessment assists the research by providing a detailed understanding of the different views towards cadastral systems.

CHAPTER 3 – REVIEW AND ASSESSMENT OF CURRENT CADASTRAL DATA MODELS

3 REVIEW AND ASSESSMENT OF CURRENT CADASTRAL DATA MODELS

3.1 INTRODUCTION

The aim of this thesis is to develop a 3D cadastral data model to manage stratified land rights, restrictions, and responsibilities and their physical counterparts. In order to develop a new data model, it is required to explore the theories and concepts of existing cadastral data models and investigate how they manage 3D data. Six major cadastral data models have been reviewed for this purpose. These data models are the most popular cadastral and land administration data models that were found in the literature and background research. They are:

- The core cadastral data model (Henssen, 1995)
- FGDC Cadastral Data Content Standard for the National Spatial Data Infrastructure (FGDC, 1996)
- ArcGIS Parcel Data Model (Meyer, 2001)
- The Legal Property Object Model (Kalantari et al., 2008)
- ePlan (ePlan, 2010)
- ISO 19152, Land Administration Domain Model (LADM) (ISO19152, 2012).

These data models were assessed and compared based on selected criteria. The aim was to analyse how they manage stratified RRRs and meet 3D cadastre’s requirements and what data modelling techniques they use to support 3D data.

3.2 ASSESSMENT CRITERIA OF CADASTRAL DATA MODELS

The criteria were selected in a way to be able to assess the data models from different aspects and provide information on how they manage stratified RRRs. Ten criteria were developed in order to assess these data models. They helped to explore each data model in detail. Table 3.1 summaries the criteria used for comparing the above-mentioned cadastral data models.

Table 3.1: Criteria for comparing current cadastral data models

Criteria	Description
a) Core objects	What are the core objects of the data model? (person, right, spatial unit, parcel)
b) Basic spatial unit	What are the basic spatial units of the data model? (2D parcel, 3D parcel)
c) Other forms of spatial units	Does the data model have other forms of spatial units? (text-based, point-based)
d) Reference documents	What are the data sources? (survey plans, architectural plans, titles, deeds, mortgage)
e) Applications	For what applications can the data model be used? (registration, taxation, valuation, planning, etc.)
f) Inclusion of other types of interests	Whether or not other types of interests are considered in the data model? (utility network right, biota right, mineral right)
g) Temporal aspects	Whether or not temporal aspects of interests are considered? (time the right is created or terminated)
h) Management and representation of stratified RRRs	How does the data model render stratified RRRs? (projection on the ground level, 3D primitives)
i) Semantic-level	At what level does the data model support semantics? (class-level, attribute-level, geometry level)

j) Physical objects	How does the data model support the physical counterparts of legal objects? (internally [in the model], externally [external databases])

This assessment enables an understanding to be gained of important cadastral data models, their advantages and disadvantages for developing a new data model. Each data model is reviewed in the following sections.

3.3 THE CORE CADASTRAL DATA MODEL

This plain data model emphasises an unambiguous registration of the concerned subject (*man*) and object (*parcel*) in land registration (Figure 3.1). Each parcel as a main geometrical component of cadastre must have an identifier (parcel number) to link to its legal information in the land registry. Descriptive information of the cadastre should contain physical attributes of the parcel such as *identifier*, *local location*, *area*, *value*, *proprietor* and/or *taxpayer* (Henssen, 1995).

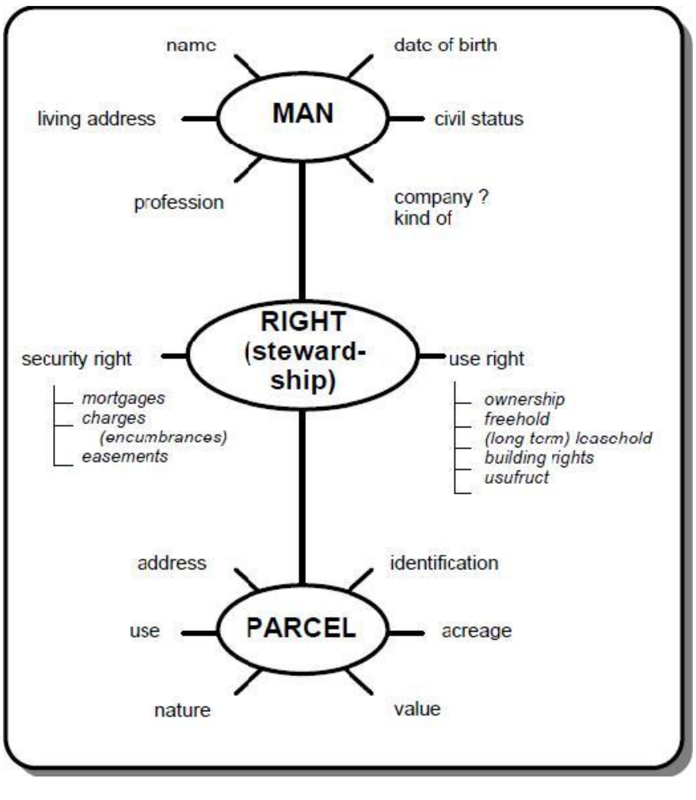


Figure 3.1: Core Cadastral Data Model (Henssen, 1995)

a) What are the core objects of the data model?

Core objects of the data model are: *Man*, *Right*, and *Parcel*.

- *Man*: based on the legal principle of specialty, in the land registry and the documents submitted for registration, the concerned subject (*man*) must be unambiguously identified in a special short manner (Henssen, 2010).

  Besides the usual indication of the subject (*man*) by name, the use of personal identification number of a man could obviously be convenient also in the land register and relevant documents. However, there are sometimes privacy constraints because the use of the personal information in automated systems brings the possibility of combining sensitive personal data (Henssen, 2010).

- *Right* (stewardship): based on the legal booking or register principle, a change in real rights on an immovable property, especially by transfer, is not legally effectuated until the change or the expected right is booked or registered in the land registry (Henssen, 2010).

- *Parcel*: The concerned object (land parcel) must be unambiguously identified in the land registry and submitted documents (Henssen, 2010).

b) What are the basic spatial units of the data model?

Parcel is the only basic spatial unit of the data model.

c) Does the data model have other forms of spatial units?

Henssen (1995) describes the parcel as the heart of a cadastre. A parcel is defined as a continuous area of land within which unique and homogeneous interests are recognised.

No other forms of spatial units are considered in the data model.

d) What are the data sources (reference [legal] documents)?

Various transaction evidences are used as reference documents (Table 3.2). As described before, they can be used if they are registered in the land registry. Mortgages are also used as reference document.

Table 3.2: Type of reference documents (Larsson, 1991)

Means of transaction	Evidence
Oral agreement	Witness
Private conveyance	Deed No registration
Deeds registration	Registration No guarantee
Title registration	Registration Proof of title

e) For what applications can the data model be used?

The data model can be used for:

- valuation and taxation of land
- registration of land and security of land tenures
- development of land acquisition and delivery (land market)
- spatial or physical planning (including sustainable management and control of land use, natural resources and the environment)

f) Does the data model have other types of interests (rights)?

Ownership, freehold (long-term) leasehold, building rights, usufruct, encumbrances, easements, and mortgage information are considered in the data model.

Other types of interests such as utility network rights, biota rights are not considered in the data model.

g) Does the data model consider temporal aspects of interests?

Transaction date is maintained in the reference documents. However, it is not clear how the data model will manage the temporal information.

h) How does the data model render stratified RRRs?

Land parcel is the only basic spatial unit of the data model. The core cadastral data model does not support 3D data.

Stratified RRRs are projected on the ground land parcel and they are not rendered with 3D primitives.

i) At what level does the data model support semantics?

Semantics are used to define objects and attributes of the data model. However, the data model does not define the geometrical description of its spatial unit (parcel). It is not clear, for example, whether the parcel will be created by textual notations, line segments, or a closed polygon.

j) How does the data model support the physical counterparts of legal objects?

Land in relation to land registration and cadastre includes not only abstract or thematic attributes (legal status, value, tax data) but also physical, spatial or topographic ones (location, dimensions, area, use) (Henssen, 1995).

- Land parcel is the representation of both legal and physical objects.

Overall, the core cadastral data model is a conceptual data model to explain the basic element of cadastre. Although 3D data has not been considered in this model, it is being used as a base model for developing a new 3D cadastral data model.

3.4 FGDC STANDARD REFERENCE MODEL

The FGDC Standard Reference Model defines data content standards as standards that provide semantic definitions of a set of objects in the United States (Figure 3.2). Data content standards may be organised and presented in a data model such as an entity-relationship model. The Cadastral Data Content Standard provides semantic definitions of objects related to land surveying, land records, and landownership information (FGDC, 2008).

The aim is to provide 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.

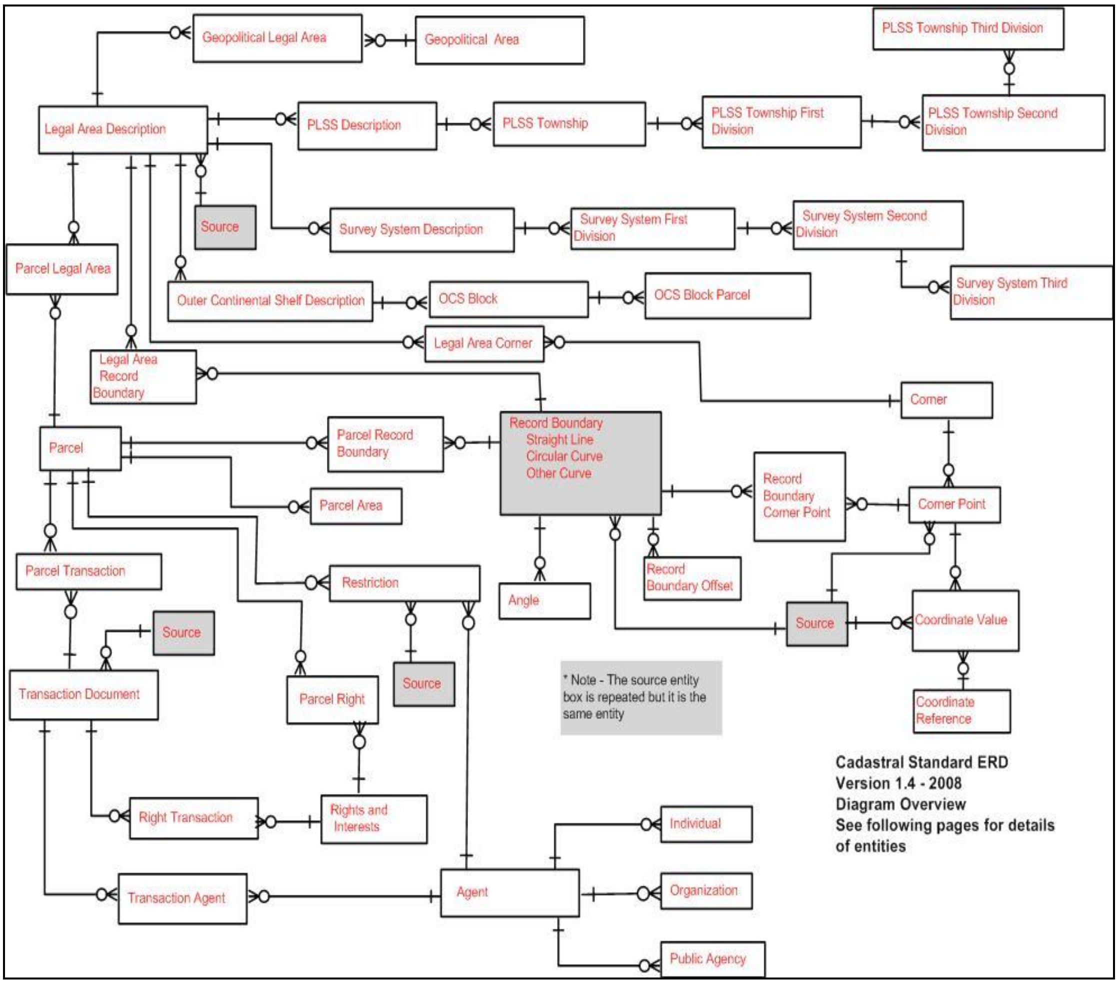


Figure 3.2: Entity and Relationship Definition Standard Entity Relationship Diagram Overview (FGDC, 2008)

a) What are the core objects of the data model?

Core objects of the data model are: *Agent*, *Right and Interest*, and *Parcel*.

- *Agent*: An *agent* is an individual, organisation, or public agency that holds rights, interests, or restrictions in land, holds or files land records, or has established a land description, a coordinate value or a monument.

  Examples of *agents* are: federal, tribal, state, regional, county, local, private, regulated, not-for-profit, international.

- *Right and Interest*: This entity describes the specific rights and interests that are related to a parcel. *Rights* and *interests* are benefits or enjoyments in real property that can be conveyed, passed, or otherwise allocated to another for economic remuneration. *Rights* and *interests* can be below ground, such as mineral rights, fee simple ownership on the surface, an easement for hunting or grazing or an above ground right such as transferable development right. A *Right* and *Interest* is separable and can be conveyed, either permanently or temporarily such as in a lease and is in the chain of title. The *right* and *interest* is distinguishable from a restriction, which is a limitation placed by a governing body and is not in the chain of title.

- *Parcel*: A p*arcel* is a single cadastral unit, which is the spatial extent of the past, present, and future rights and interests in real property.

  Parcel types can be Taxable, Right of Way, General Common Element, Water, and Ownership.

b) What are the basic spatial units of the data model?

Parcel is the only basic spatial unit of the data model.

c) Does the data model have other forms of spatial units?

No other forms of spatial units are considered in the data model.

d) What are the data sources (reference [legal] documents)?

The source is the feature level information about the originating information for the record. This should be the authoritative source for the data. For federal land records information on legislative or executive authorisations may be added to source information. Example of source types are (FGDC, 2008): abstract of title, aerial photographs, agreements, assessments, bylaws, certificates, certificate survey, contracts, covenants and restrictions, deeds, easements, executive orders, lease, mortgages, satellite images, survey notes.

e) For what applications can the data model be used?

The data model can be used for:

- model cadastral information in the public record
- automating the legal elements of cadastral data found in public records
- integration of publicly available land records information
- standardisation of the definition of entities and objects related to cadastral information including survey measurements, transactions related to interests in land, general property descriptions, and boundary and corner evidence data.

f) Does the data model have other types of interests (rights)?

The types of interests are:

- separated rights: mineral and oil rights
- tribal interests
- grazing rights, fishing rights, development rights, and floodplains.

g) Does the data model consider temporal aspects of interests?

The *Transaction Document* keeps the record of the transfer of rights in land using these attributes: *Effective Date*, *Expiration Date*, *Recorded Date*, and *Recorded Time*.

h) How does data model render stratified RRRs?

Land parcel is the only basic spatial unit of the data model. The data model does not support 3D data.

Stratified RRRs are projected on the ground parcel and they are not rendered with 3D primitives.

i) At what level does the data model support semantics?

The Cadastral Data Content Standard is shown as an entity relationship diagram (Figure 3.2). The diagram describes the semantics of cadastral information. Entity relationship diagrams are a shorthand method for showing the associations or relationships among various objects and hence the definitional relationships of the objects or features.

Semantics are used to define geometry of the spatial unit (parcel) using record *Boundary Corner point*, *Straight Line*, *Coordinate Value*, *Curve*, and *Angle* objects.

j) How does the data model support the physical counterparts of legal objects?

Land parcel is the representation of both legal and physical objects.

Overall, FGDC' Cadastral Data Content Standard diagrams describe the definitions and semantics of cadastral information. 3D data has not been considered in this model.

3.5 ArcGIS PARCEL DATA MODEL

The purpose of the ArcGIS Parcel Data Model is to describe parcel information to support local government and private sector decision making (Figure 3.3). Parcel managers and GIS professionals can use the model as a starting point for defining parcel information in the GIS environment and plan for migration strategies from current data designs to the new object environment. Decision makers will be able to apply the outcome of the model to integrate land ownership information with other data. Land and GIS professionals will be able to apply the definitions and structure of the model to find consistent and representative parcel information for data distribution.

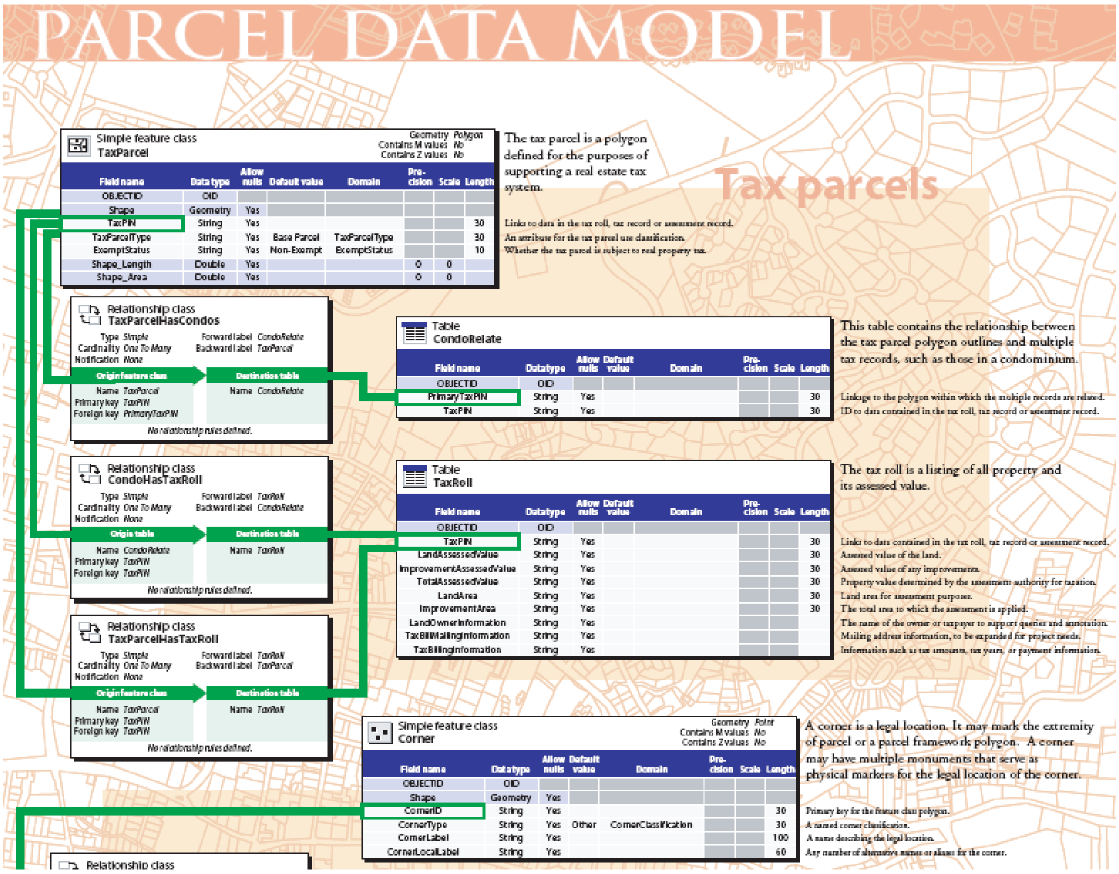


Figure 3.3: Part of the ArcGIS Parcel Data Model

a) What are the core objects of the data model?

Core objects of the data model are: *Ownership*, *Encumbrances*, and *Separated Rights*.

- *Ownership Parcel*: a parcel is a unit of real property with rights and interests.
- *Encumbrances*: limitations on the rights and use of the land.
- *Separated Rights*: rights and interests in land ownership that can be disconnected from the primary or fee simple surface ownership.

b) What are the basic spatial units of the data model?

Parcel is the only basic spatial unit of the data model.

c) Does the data model have other forms of spatial units?

No other forms of spatial units are considered in the data model.

d) What are the data sources (reference [legal] documents)?

All legal and authoritative documents such as deeds, survey plans, mortgages and lease contracts are used as a source of information.

e) For what applications can the data model be used?

The data model can be used for:

- development of parcel level management
- support parcel level functionality in the GIS environments.

f) Does the data model have other types of interests (rights)?

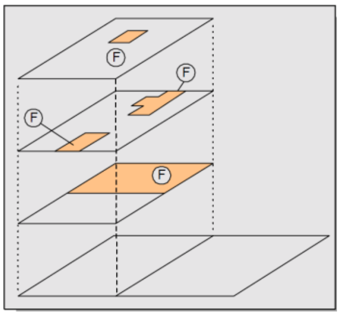
Types of rights are mineral rights, oil rights, grazing right, and fishing rights.

g) Does the data model consider temporal aspects of interests?

Temporal information (transaction date and time) is recorded in the data model.

h) How does data model render stratified RRRs?

Many jurisdictions have condominiums or other structures that can form common interest areas and three-dimensional surfaces with different owners on different levels of the structures. A condominium is a separate system of ownership of individual units in a multiple-unit building. The units or buildings in the condominium are part of the ownership parcels with a vertical aspect and are called vertical parcels in the ArcGIS Parcel Data Model (Meyer, 2004).



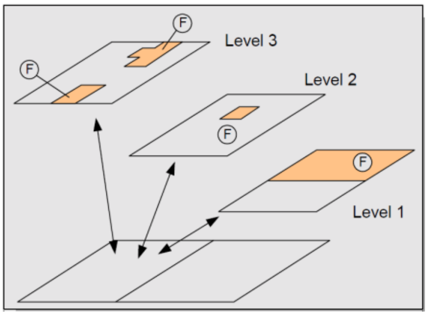


Figure 3.4: Vertical Parcels (Left) and a method of representing vertical points (Right) (Meyer et al., 2001).

Figure 3.4 illustrates a vertical parcel that is a condominium building with condominium unit F that is on three separate floors. Unit F is connected by common elements, such as stairways and elevators.

In the ArcGIS Parcel Data Model there are several ways to model or represent vertical parcels:

- single outline polygon pointing to multiple parcel records
- single outline polygon pointing to another series of polygons that represent the levels or floor
- single outline polygon that points to a three dimensional model of the building.

Stratified RRRs are projected on the polygons and they are not rendered with 3D primitives.

Three-dimensional model of the building is not supported in the model.

i) At what level does the data model support semantics?

Semantics are used to define the model's classes, attributes and parcel geometry.

j) How does the data model support the physical counterparts of legal objects?

Land parcel is the representation of both legal and physical objects.

Overall, the ArcGIS Parcel Data Model is a general and flexible data model that helps users to manage land parcels using GIS technology. Vertical parcels (condominium) are supported in the data model; however, 3D primitives are not used to represent the vertical parcels.

3.6 THE LEGAL PROPERTY OBJECT MODEL

The concept of the *Legal Property Object* is based on the combination of the interest and its spatial dimension (Figure 3.5). It stands on the reality that land is converted into a legal entity when an interest is attached to it. The *Legal Property Object* re-engineers the concept of the Core Cadastral Data Model from a land parcel-based data model to a spatially referenced data model. This new initiative is able to include all interests in land comprehensively and accommodate the increasing number of new interests on land (Kalantari et al., 2008).

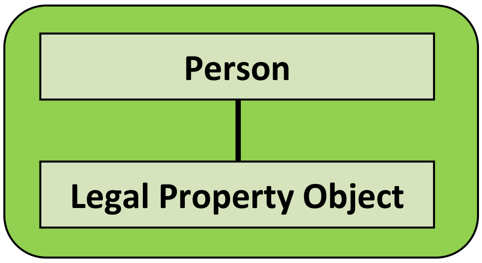


Figure 3.5 The Legal Property Object model (Kalantari et al., 2008)

a) What are the core objects of the data model?

Core objects of the data model are: *Person* and *Legal Property Object*.

- *Person*: The *person* includes all the private, natural and non-natural individuals as well as the public.

- *Legal Property Object*: The *Legal Property Object* includes a particular interest with its spatial dimensions. The *Legal Property Object* will be the basic building block and is the centre of the model for organising land information.

b) What are the basic spatial units of the data model?

The *Legal Property Object* is the only basic spatial unit of the data model.

c) Does the data model have other forms of spatial units?

Every object will be treated as a separate *Legal Property Object.*

d) What are the data sources (reference [legal] documents)?

Legal Document class represents the legal data source in the model to create required information of the *Legal Property Objects*. It certifies the interests to be granted to a rightful claimant. A very common legal document would be a land ownership title. The legal document class in fact has an external functionality by providing an evidence of *Legal Property Object* for a rightful claimant to a third party. Each legal document is the description of a legal property object and associated rightful claimants.

e) For what applications can the data model be used?

The *Legal Property Object* model facilitates the land administration system to be more extensible and scalable in terms of new legislations and land-related laws. The new laws can be applied to individual legal property objects. Therefore the relationship between various legal property objects, like relationship between a water right and a land right on a specific location, can be formulated using specific rules in the data model.

f) Does the data model consider temporal aspects of interests?

The *Legal Property Object* class consists of a set of sub-classes each related to a particular interest in land. In practice, the *Legal Property Object* will be that all interests attached to land will be held separately from the land ownership, and the other interests attached to land will be viewable on a title search, putting the world on notice of the interests and complex commodities that flow with that land. The model proposed in this research has picked up the most common interests and complex commodities that currently land administration systems are dealing with. They are:

- parcel Ownership
- property ownership
- tax responsibility
- biota right
- mineral right
- easement restriction.

g) Does the data model consider temporal aspects of interests?

Temporal information (transaction date and time) is recorded in the *Legal Document* class.

h) How does data model render stratified RRRs?

An interest in land is not necessarily equivalent in area to an exact extension of a particular land parcel; indeed, it may be applied across several land parcels (Figure 3.6).

Land parcels are not flexible enough to accommodate non-parcel based interests. Every interest will be treated as a separate *Legal Property Object* and will spatially link to the related *Legal Property Objects.*

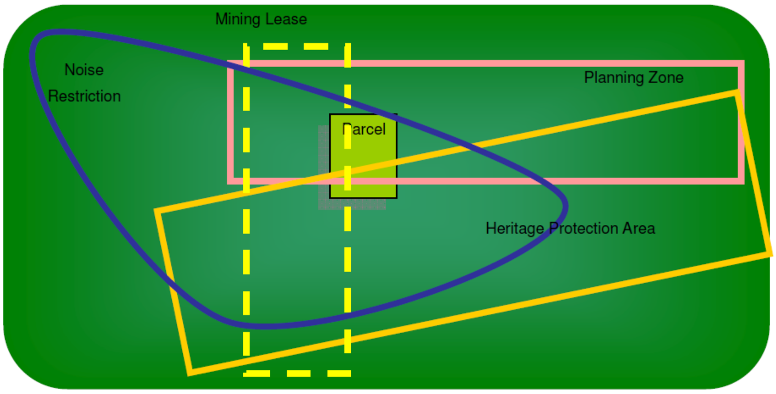


Figure 3.6: An example of non-parcel based interests (Kalantari, 2008).

i) At what level does the data model support semantics?

Semantics are used to define the model's classes and attributes. However, the data model does not define the geometrical description of *Legal Property Object*.

j) How does the data model support the physical counterparts of legal objects?

Physical counterparts of the *Legal Property Objects* are not considered in the data model.

Overall, the advantage of this model is the comprehensive inclusion of all interests in land. The proposed model addresses the issue of the ever-growing number of interests in land and shifts the whole land administration functionality to be based on a data model with *Legal Property Objects* at its heart. In short, ultimately the system allows all rights, restrictions and responsibilities, and commodities to be registered spatially in a holistic way as represented in Figure 3.7. However, the geometry package used to represent the *Legal Property Objects* contains *Point*, *Curve*, and *Surface* objects. 3D primitives are not used to represent the *Legal Property Objects*.

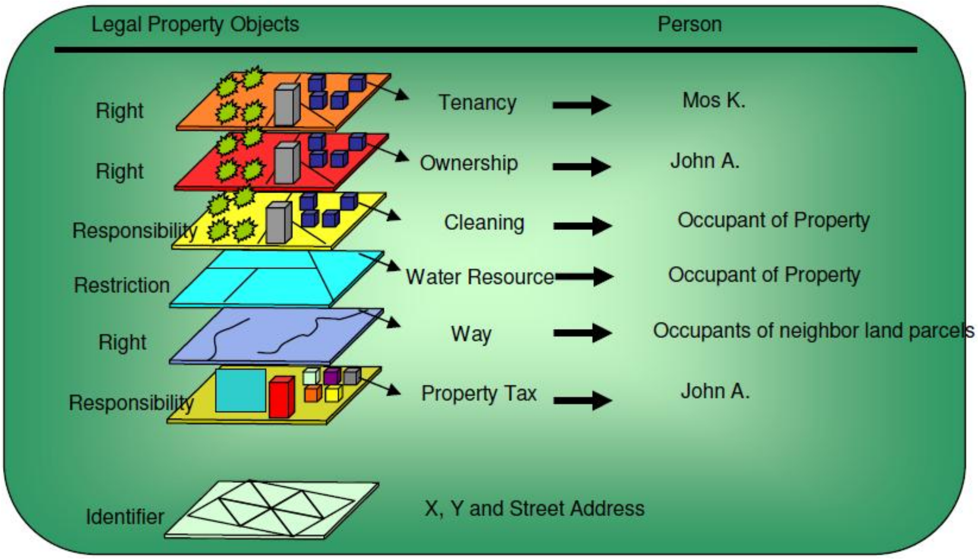


Figure 3.7: Spatially registering Legal Property Objects (Kalantari, 2008).

3.7 ePLAN MODEL

The ePlan model was developed to model geometrical and textual information of Australian survey plans under the direction of the Intergovernmental Committee on Surveying and Mapping (ICSM). It inherits the ISO standards and rules of Australia's Harmonized Data Model (HDM) (Figure 3.8). HDM was developed to facilitate the compilation of national data sets from data supplied by jurisdictions (ICSM, 2008a).

The ePlan model accommodates all of the survey geometry and administrative and titling data required to process a plan of subdivision from its initial preparation by the surveyor through to its lodgement with council for certification and subsequent registration (Kalantari et al., 2009).

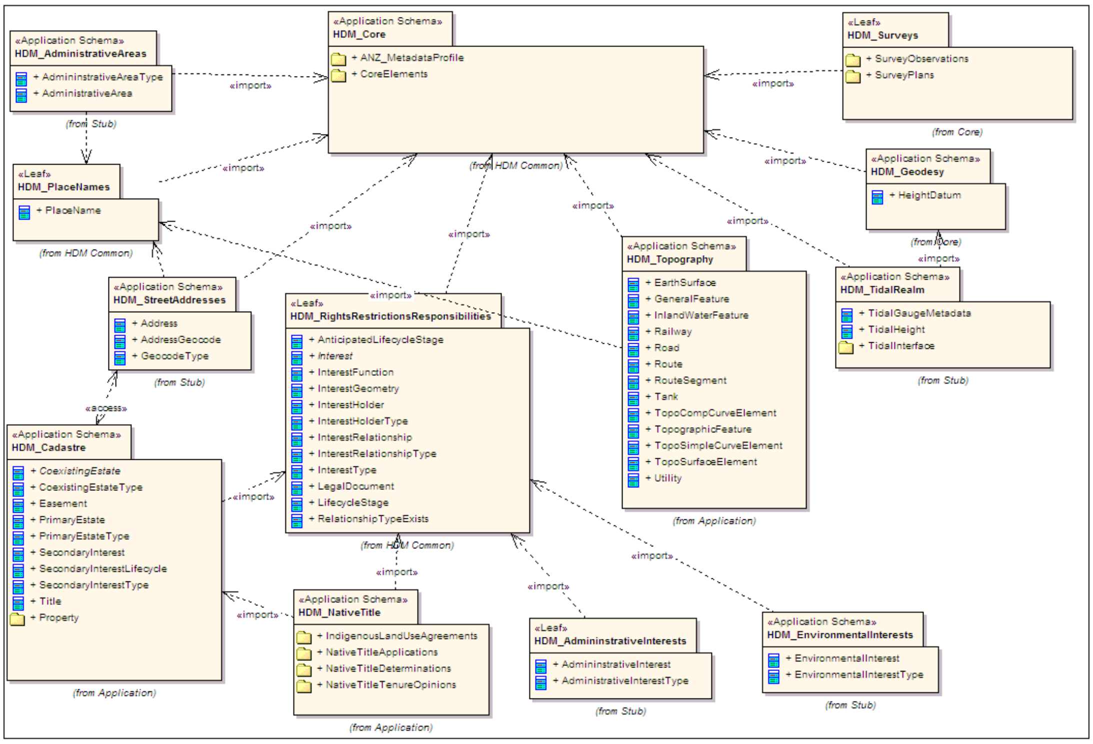


Figure 3.8: HDM's Package Diagram (ICSM, 2008a)

The ePlan model has been classified into a number of packages (Figure 3.9). They are *Document*, *Surveyor*, *Survey*, *Parcel*, *Address*, *Geometry*, *Point*, and *Observation* (Figure 5). 2D land parcels form the basis of ePlan. All administrative information is collected based on the land parcels, which are defined in the parcel package of the model (Kalantari et al., 2009).

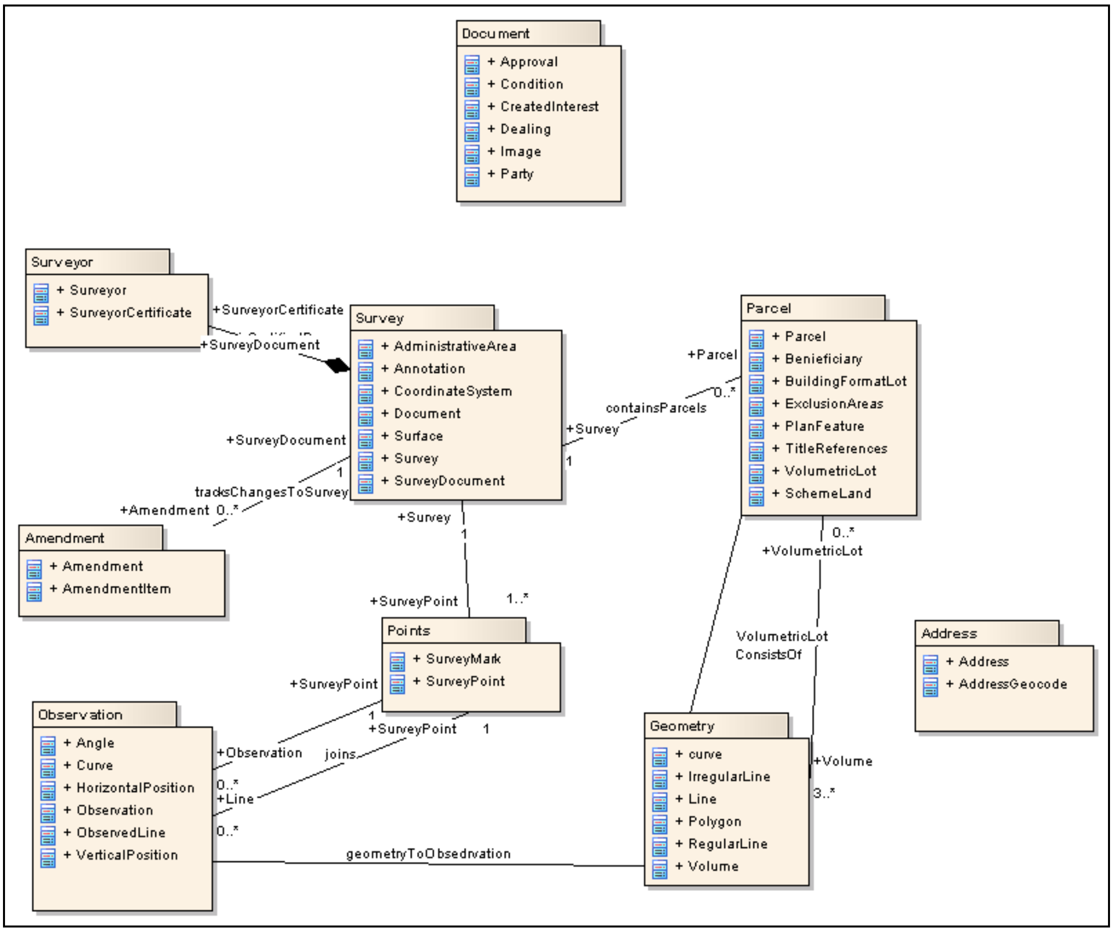


Figure 3.9: ePlan Model packages (ePlan, 2010)

a) What are the core objects of the data model?

Core objects of the data model are: *Parcel*, *Document*, *Survey*, *Surveyor*, *Observation*, *Address*, *Point*, and *Geometry*.

- *Parcel*: The *parcel* element provides a basic unit to describe a spatial area.
- *Document*: Any other legal documents that define rights or ownership of land attached to the *parcel*.
- *Survey*: The *survey* element contains the survey components of the ePlan such administrative information (*surveyHeader*), observation elements (*Observationgroup*), and observation setup points (*InstrumentSetup*).
- *Observation*: Observation elements.
- *Address*: Street address information for the parcel.

- *Surveyor:* information about the surveyor who participated in the survey.
- *Point*: Various administrative points such boundary points, traverse points, reference marks, and permanent survey marks.
- *Geometry*: Consists of *Curve*, *IrregularLine*, *Line*, *Polygon*, *RegularLine*, and *Volume* to represent geometry of the parcel.

b) What are the basic spatial units of the data model?

Parcel is the only basic spatial unit of the data model.

BuildingFormatLot and *VolumetricLot* are used to describe 3D legal objects.

c) Does the data model have other forms of spatial units?

No other forms of spatial units are considered in the data model.

d) What are the data sources (reference [legal] documents)?

Title, *Approval*, *Dealing* and any other legal documents that defines rights or ownership of land attached to the parcel are used as sources of information.

e) For what applications can the data model be used?

They can be used to:

- eliminate the current reliance on hardcopy or PDF plans
- improve the quality of plan data and associated documents
- improve plan examination processing
- reduce requisitions
- enhance the accuracy of the Digital Cadastral Database.

f) Does the data model have other types of interests (rights)?

Primary parcels are based level parcels that form the continuous cadastral fabric. They consist of lots, roads, reserves, common property, crown parcels and staged lots. In ePlan, they are captured using the parcel element (ePlan, 2010).

Secondary interests in cadastral survey plans provide benefits and/or pose restrictions on primary cadastral parcels. These include easements, restrictions and depth limitations (ePlan, 2010).

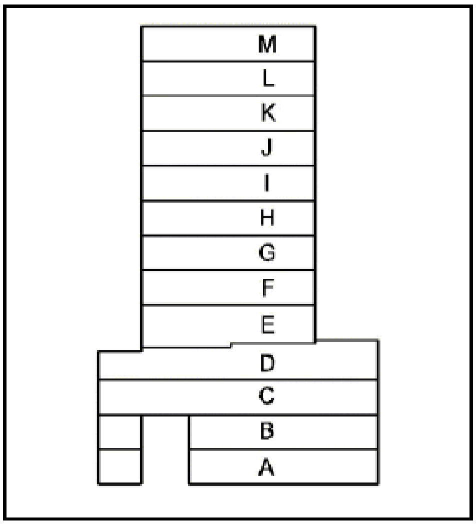
g) Does the data model consider temporal aspects of interests?

Temporal information such as transaction date, surveying date, and administrative date is recorded in the data model.

h) How does data model render stratified RRRs?

Each Australian state and territory has modified the ePlan's national protocol specification (ePlan, 2010) to cater for its requirements. For example, the Victorian ePlan version does not support volumetric lots and ePlan's 3D elements, such as *VolumetricLot* (3D parcel) and *VolumeGeom* (3D primitive), have been excluded from the Victorian ePlan model (ePlanVictoria, 2010). In Victoria, stratified interests are represented as 2D parcels.

Queensland, in contrast, supports 3D parcels and defines the properties of a 3D coordinate geometry collection (ePlanQueensland, 2010). Building Format Plan and Volumetric Format Plan are two types of 3D parcels (Figure 3.10).



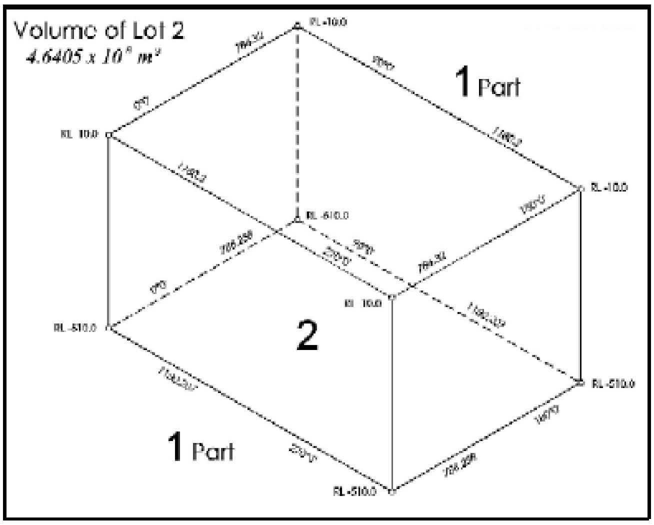


Figure 3.10: Building Format Plan (Left) and Volumetric Format Plan (Right) (DERM, 2011).

In Queensland, if the format of the parcel is Building or Volumetric, it is mandatory to use building level number (*BuildingLevelNo*) and volumetric geometry (*VolumetricGeom*) to represent stratified interests (ePlanQueensland, 2010).

i) At what level does the data model support semantics?

Semantics are used to define the model's classes and attributes. However, the data model does not define the geometrical description of parcel.

j) How does the data model support the physical counterparts of legal objects?

This ePlan does not support physical counterparts of legal object (parcel).

Overall, the current ePlan model has been exercised rigorously over the last several years in Australian jurisdictions. It has been designed to support 3D surveys, which include Volumetric and Strata (Building) surveys. These types of surveys can be prepared with the current protocol but have not been fully exercised (Cumerford, 2010). This ePlan is serving very well for 2D cadastre; however, having only *VolumetricLot* and *BuildingFormatLot* as attributes of ePlan's Parcel class (Figure 3.10) to support Volumetric and Strata (Building) surveys, they are not enough to support the requirements of 3D cadastre (Aien, 2012), which will be described in the next chapters.

3.8 LADM (ISO 19152)

The Land Administration Domain Model (LADM) is now the ISO standard and most recognisable data model in land administration discourse. This data model has been under development since the early 2000s. The LADM provides a conceptual description for a land administration system. The model aims to provide an extensible basis for the development and refinement of efficient and effective land administration systems and to enable involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary implied by the model (ISO19152, 2012). The concept is adaptable to, for instance, accommodating agricultural land use for purposes of the agricultural subsidy in the European Union, and recognising the social tenures used in many countries by traditional, customary, and tribal people through the Social Tenure Domain Model (Lemmen, 2010).

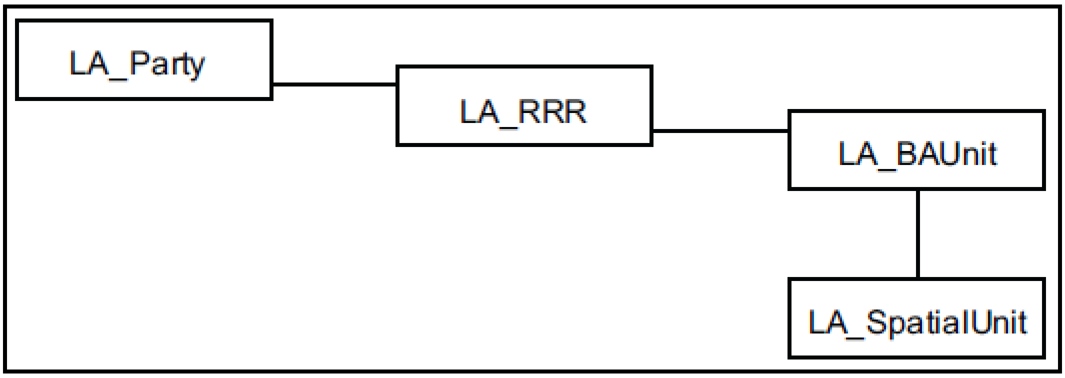


Figure 3.11: Basic classes of LADM (ISO19152, 2012)

a) What are the core objects of the data model?

LADM has four basic classes (Figure 3.11). They are *LA_Party*, *LA_RRR*, *LA_BAUnit*, and *LA_SpatialUnit* (ISO19152, 2012).

- *LA_Party*: A person or organisation that plays a role in a rights transaction.
- *LA_RRR*: *Right* (action, activity or class of actions that a system participant may perform on or using an associated resource), *Restriction* (formal or informal obligation to refrain from doing something), *Responsibility* (formal or informal obligation to do something).
- *LA_BAUnit*: A Basic Administrative Unit is an administrative entity, subject to registration (by law), or recordation consisting of zero or more **spatial units** against which (one or more) unique and homogeneous rights, responsibilities, or restrictions are associated to the whole entity, as included in a land administration system.
- *LA_SpatialUnit*: A single area (or multiple areas) of land and/or water, or a single volume (or multiple volumes) of space. Spatial units are structured in a way to support the creation and management of basic administrative units.

b) What are the basic spatial units of the data model?

LA_SpatialUnit is the basic spatial unit of the data model. LADM's code lists for Spatial Unit Package represents all types of spatial units supported by LADM (Figure 3.12).

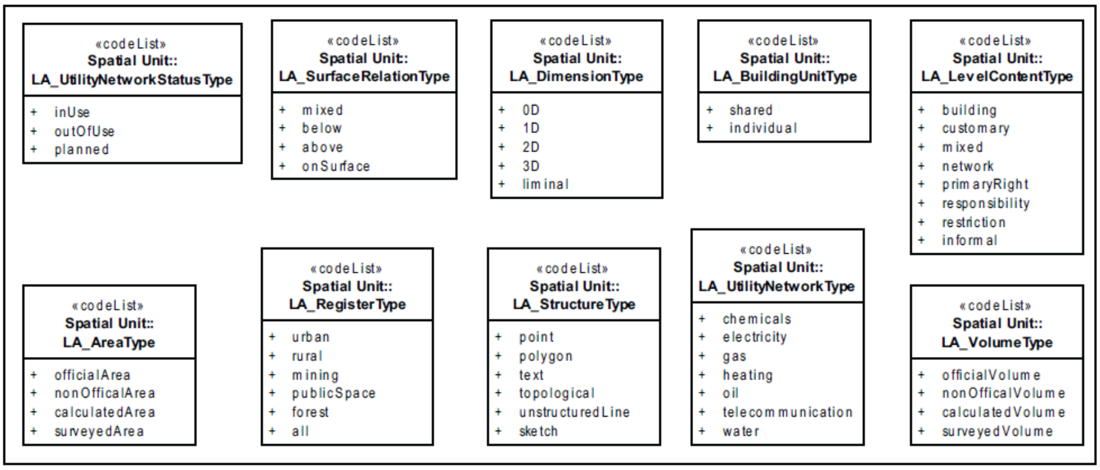


Figure 3.12: Code lists for Spatial Unit Package (ISO19152, 2012)

c) Does the data model have other forms of spatial units?

Yes, LADM's spatial component (*LA_SpatialUnit*) supports many ranges of spatial units such as *Sketch-based*, *Text-based*, *Point-based*, *Line-based*, *Polygon-based*, and *Topology-based* units. These spatial units are applicable in different land administration systems.

d) What are the data sources (reference [legal] documents)?

The data sources are all documents providing legal and/or administrative facts on which the land administration objects such as rights, restrictions, responsibility, basic administrative units, parties, or spatial units are based on. Deeds, titles, mortgages, agreements are examples of administrative or legal documents.

e) For what applications can the data model be used?

The data model can be used for a number of land administration applications.

f) Does the data model have other types of interests (rights)?

LADM's code lists for the administrative package that represents all types of interests supported by LADM (Figure 3.13).

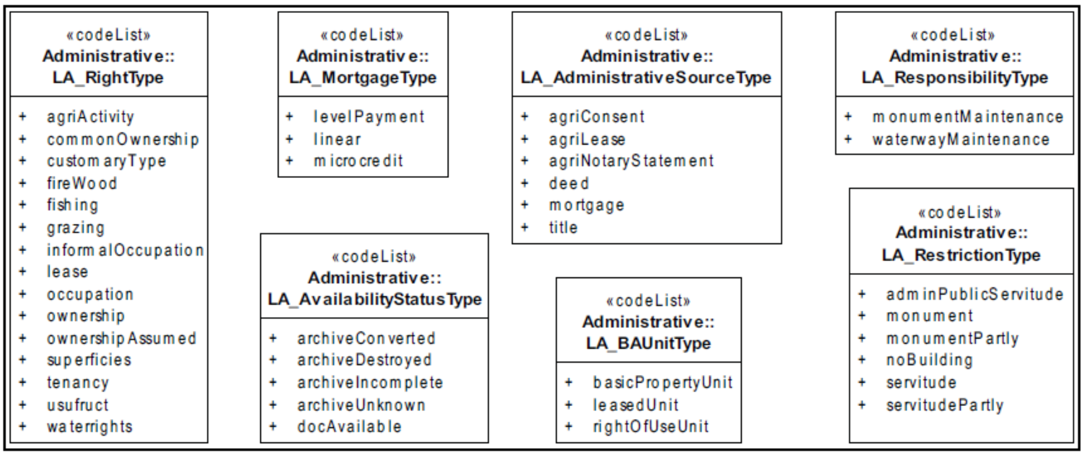


Figure 3.13: Code lists for Administrative Package (ISO19152, 2012)

g) Does the data model consider temporal aspects of interests?

Yes. LADM covers history and dynamic aspects. *Class VersionedObject* is introduced in the LADM to manage and maintain historical data in the database. History requires, that inserted and superseded data, are given a time-stamp. In this way, the contents of the database can be reconstructed, as they were at any historical moment. Most of LADM's classes are subclasses of *Class VersionedObject* (Figure 3.14).

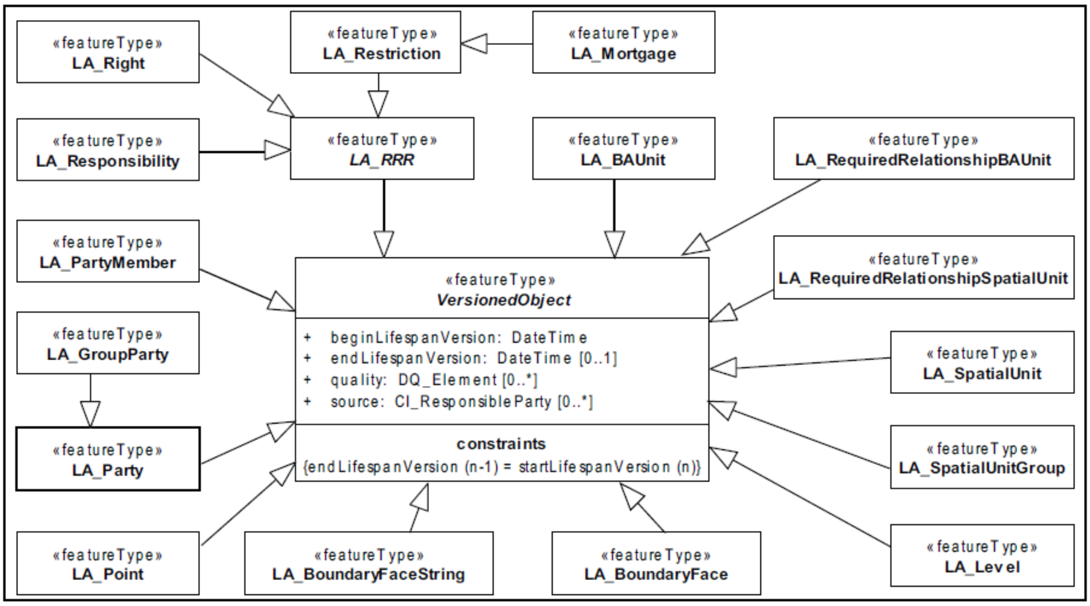


Figure 3.14: Classes VersionedObject (with subclasses) (ISO19152, 2012)

h) How does data model render stratified RRRs?

LADM has a solution to represent stratified interests and 3D parcels using *Class LA_BoundaryFace*. However, the LADM does not use solid geometry (*GM_Solid*) to represent 3D parcels. Pouliot et al. (2011) also suggests how solid representation can increase LADM's 3D functionalities. Solid geometry facilitates 3D representation, volumetric calculation, and 3D spatial analysis.

LADM uses *Class LA_BoundaryFaceString* to represent 2D *LA_SpatialUnit* such as land parcels, and *Class LA_BoundaryFace* to represent 3D *LA_SpatialUnit* such as 3D parcels (apartment units). These classes are defined by associating to *Class LA_Point* and *Class LA_SpatialSource* (survey documents).

LADM also utilises ISO 19107's *GM_MultiCurve* and *GM_MultiSurface* geometry objects to represent *Classes LA_BoundaryFaceString* and *LA_BoundaryFace* respectively. They are included as attributes of those classes (Figure 3.15). At least three points are needed to define a *LA_BoundaryFace* (triangle) and four *LA_BoundaryFaces* to create a 3D parcel (*LA_SpatialUnit*).

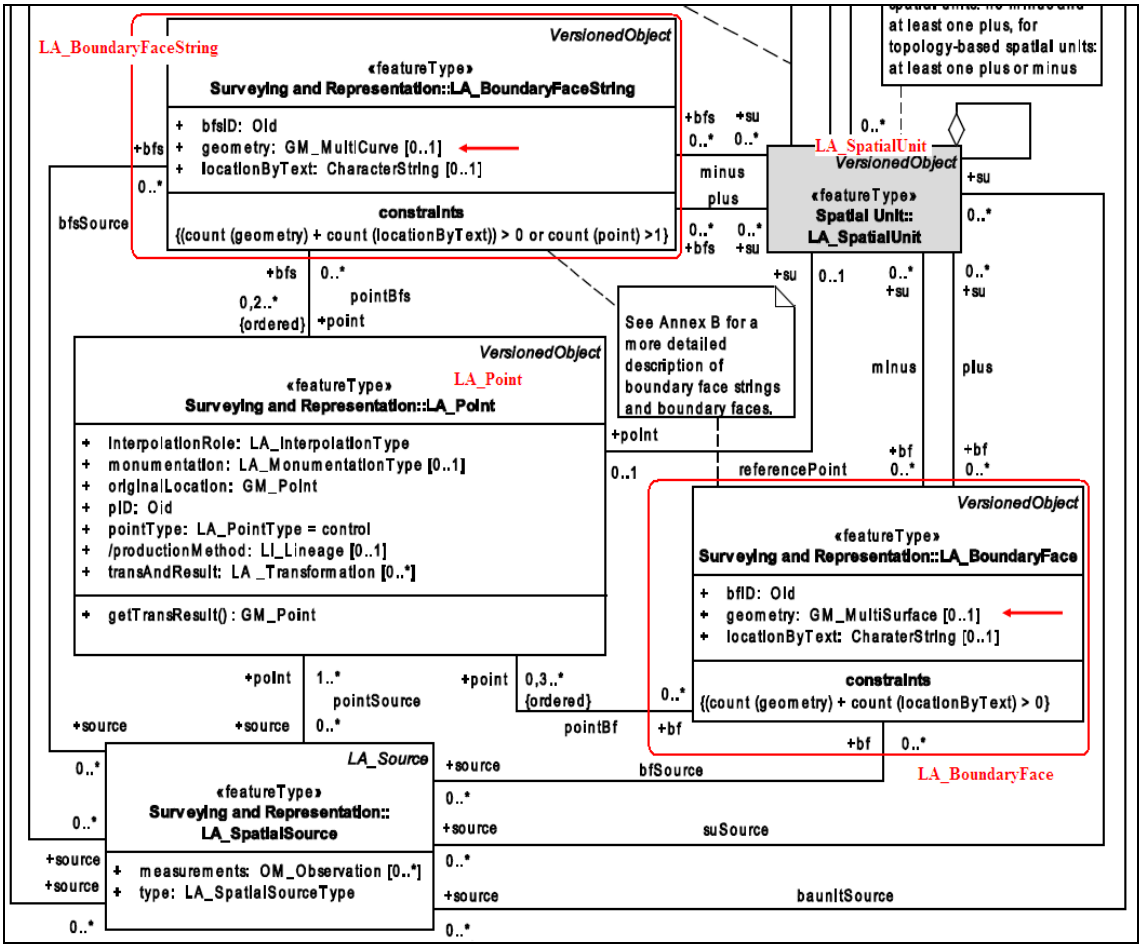


Figure 3.15: Surveying and Representation Subpackage of LADM and geometry attributes of LA_ BoundaryFace and LA_BoundaryFaceString (ISO19152, 2012)

According to ISO 19107, *GM_MultiSurface* is an aggregate class containing instances of *GM_OrientableSurface*. *GM_OrientableSurface* consists of a surface and an orientation inherited from *GM_OrientablePrimitive*, which is a subclass of *GM_Primitive*. Figure 3.16 shows that *GM_MultiSurface* only returns accumulated area and perimeter of all *GM_Surfaces* contained in the *GM_MultiSurface* and does not return volume (ISO19107, 2005). In contrast, using *GM_Solid* and *GM_CompositeSolid* in 3D cadastre data models to construct and represent 3D objects would facilitate 3D spatial analytical methods (3D buffering, overlap, intersect, etc.), interoperability for 3D data (integration, data discovery), 3D computation, and 3D visualisation (Zlatanova & Lee, 2008). Therefore, LADM's *LA_ BoundaryFace* cannot return volume of the 3D objects according to ISO 19107 standard. Table 3.3 summarises LADM's representation objects, their geometry attributes and corresponding objects in ISO 19107.

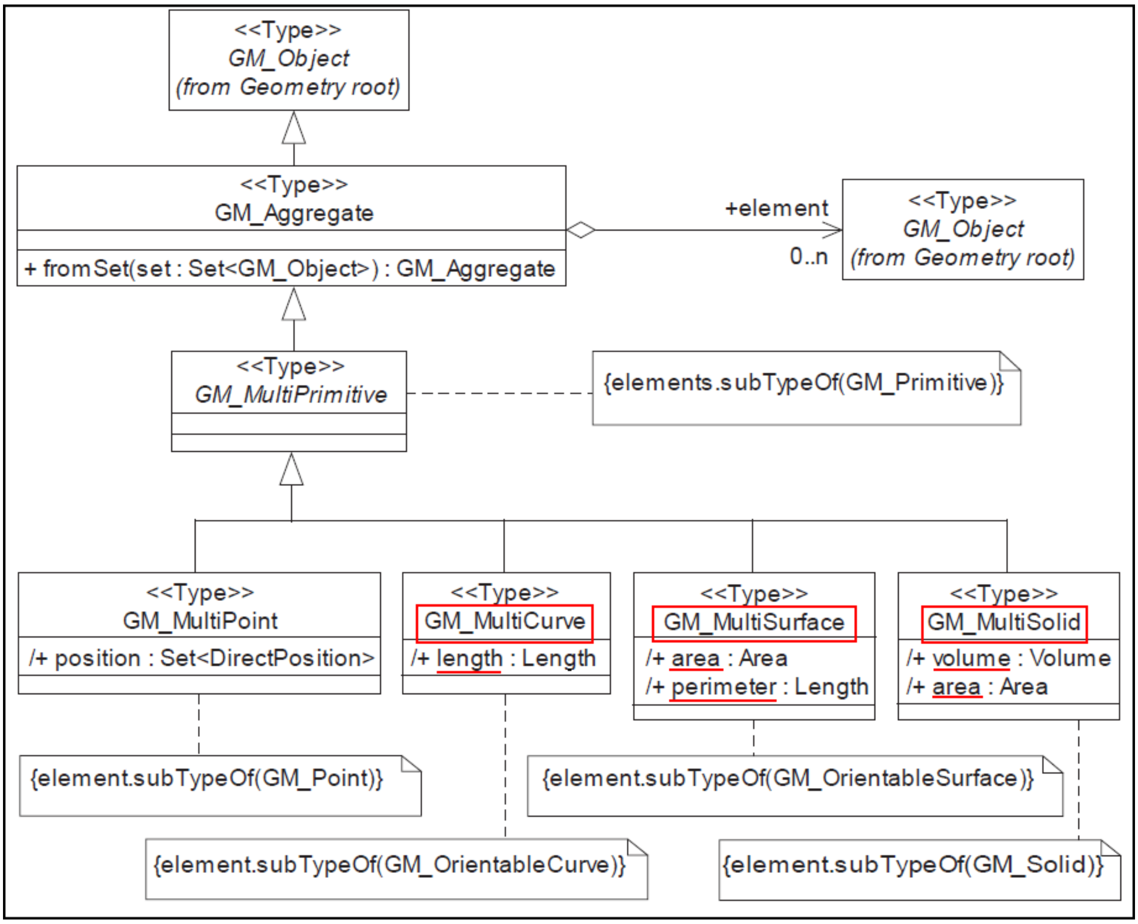


Figure 3.16: GM_MultiSurface returns accumulated area of all GM_Surfaces contained in the GM_MultiSurface (ISO19107, 2005)

Table 3.3: LADM's representation objects and their attributes

LADM's Representation Objects	Corresponding Legal Objects	LADM's geometry attributes	Corresponding attributes in ISO 19107
LA_BoundaryFaceString (Figure 3.15)	2D parcel	GM_MultiCurve [0..1] (Figure 3.15)	Returns: **length** (Figure 3.16)
LA_ BoundaryFace (Figure 3.15)	3D parcel	GM_MultiSurface [0..1] (Figure 3.15)	Returns: **area** and **perimeter**, **No** volumetric attributes (Figure 3.16)

i) At what level does the data model support semantics?

Semantics are used to define the model's classes, attributes. However, LADM's 3D geometry representation class (*LA_BoundaryFace*) does not fully support semantics.

LA_ BoundaryFace (semantic object), which is used to represent *LA_SpatialUnit* (semantic object) or its two specialisations *LA_LegalSpaceBuildingUnit* and *LA_LegalSpaceUtilityNetwork*, is not semantically enriched (Figure 3.17). A *LA_LegalSpaceBuildingUnit* that is represented by *LA_ BoundaryFace* is used to describe the extent or part of an administrative entity (*LA_BAUnit*) that is associated with one or more unique and homogenous right (*LA_Right*) such as an ownership right. In the case of apartment units, ownership rights are defined based on physical structures and bounded by walls, roofs, floors and ceilings. It must also define whether the surface boundaries are interior, median, or exterior boundaries. *LA_ BoundaryFace* does not provide such semantics and it represents merely the bound shape of a spatial unit using surfaces regardless to their definitions.

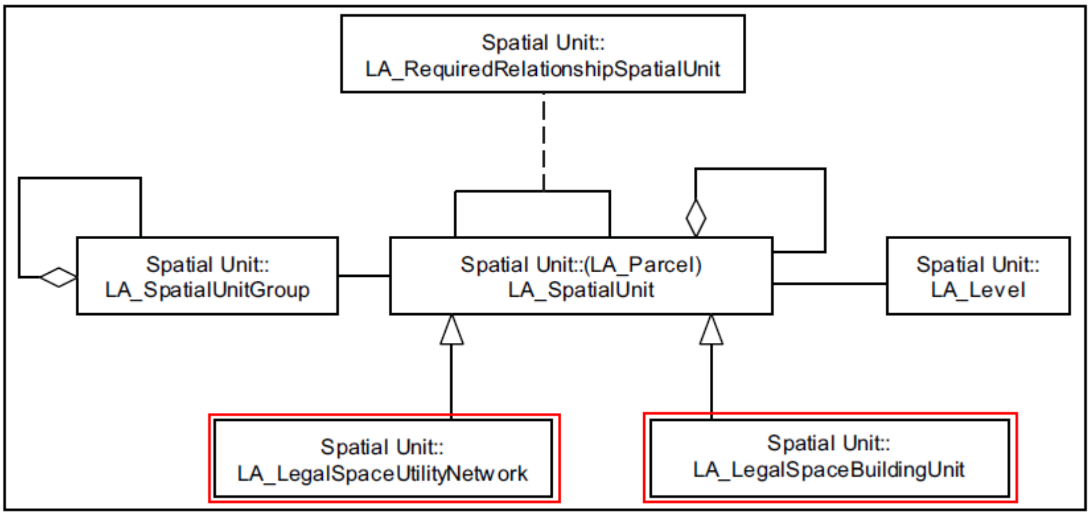


Figure 3.17: Classes of Spatial Unit Package (ISO19152, 2012)

j) How does the data model support the physical counterparts of legal objects?

LADM makes a distinction between legal and physical objects by introducing external classes. However, it is not easy to explicitly model a physical object in LADM. Using <<blueprint>> stereotype in external classes (Figure 3.18, highlighted in red colours) indicates that the classes are outside the scope of the LADM (ISO19152, 2012), which means that they are not directly created in the LADM.

As such, LADM's legal objects are connected using object identifiers to the physical objects, which are in the external databases. For example, *ExtPhysicalUtilityNetwork* is a class for the external registration of mapping data of utility networks and is associated to *Class LA_LegalSpaceUtilityNetwork*. The attributes of *ExtPhysicalUtilityNetwork* are: the flow direction, fixed or not, and the organisation responsible for the utility network (Figure 3.18).

Also, *ExtPhysicalBuildingUnit* is a class for the external registration of mapping data of building units. *ExtPhysicalBuildingUnit* is associated to class *LA_LegalSpaceBuildingUnit*. Its attribute is the identifier (*extAddressID*), pointing to the external address (Figure 3.18).

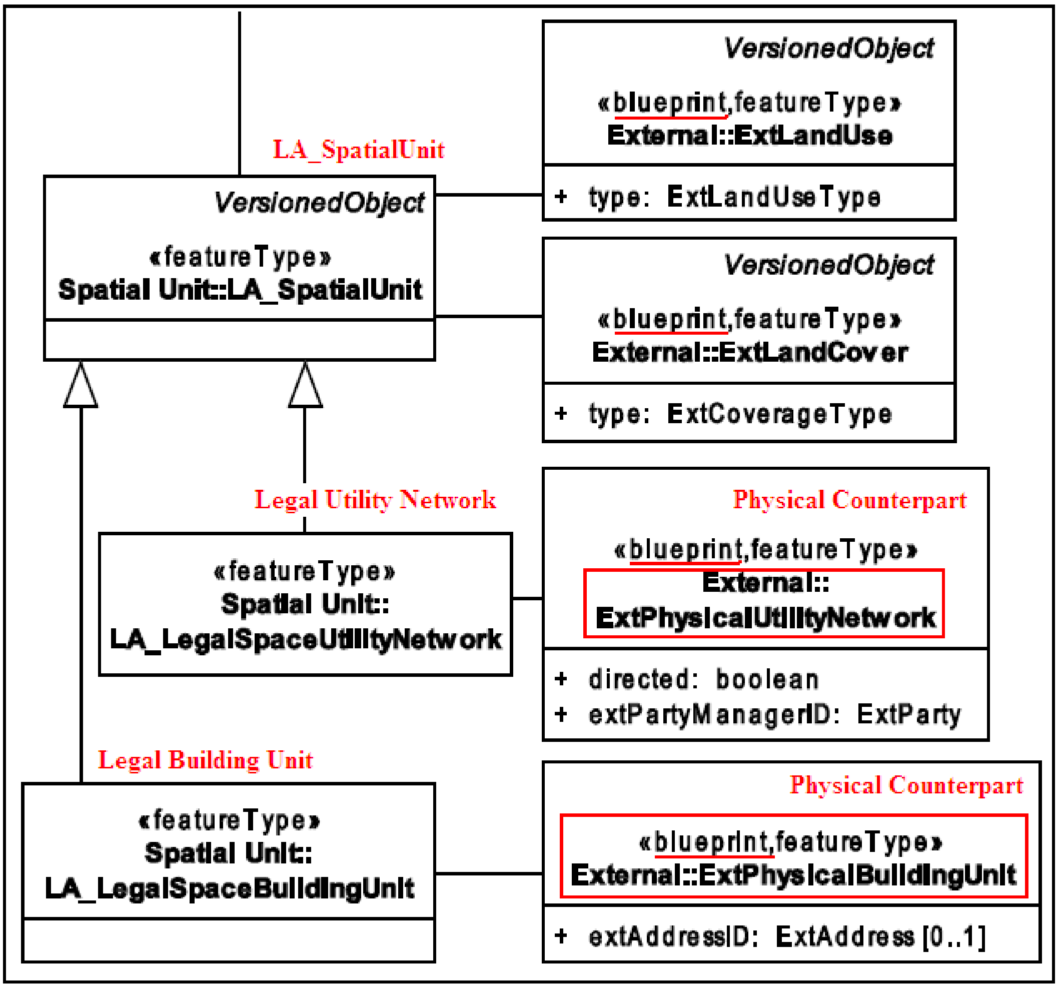


Figure 3.18: External classes such as ExtPhysicalUtilityNetwork and ExtPhysicalUtilityNetwork in relation to LADM's LA_SpatialUnit class (ISO19152, 2012)

Overall, LADM is an ISO standard that can be used as a basis for land administration system developments. It enables communication between land administration parties, both within one country and between different countries, based on the shared vocabulary implied by the model. However, implementation of LADM is not obvious (Pouliot et al., 2011). It supports 3D representation of interest. But, semantics are not fully supported by the data model in terms of geometry representation.

In this model, the legal and physical objects are kept in different sources and are manipulated by different data providers. Diversity in data providers would create inconsistency in the integration of datasets, including institutional, technical, social, legal, and policy heterogeneity (Mohammadi et al., 2010). As a result, legal models may not match with their corresponding physical models in this data models.

3.9 SUMMARY OF THE MODELS AND THE ASSESSMENT TABLE

Six cadastral data models have been reviewed in order to understand the advantages and experiences when developing the 3D cadastral data model. Actually, a few more data models such as DM.01 (Steudler, 2005), Hormonised Data Model (ICSM, 2008a), South Korean Cadastral Data Model (Lee & Koh, 2007; Park et al., 2010) were investigated in this research; however, only six of them were chosen because they were well documented and accessible to the researcher.

Although cadastral data models vary among jurisdictions, they rely on the basic building block of a 2D land-parcel. Current cadastral data models have been developed based on the definition of a 2D land-parcel (Kalantari et al., 2008). This trend is working satisfactorily for areas where no layered and stratified land rights exist. However, for 3D developments above and below ground, such as apartments, multi-story buildings, tunnels, and utilities, a 2D land parcel is no longer the most effective building block of cadastres; it is replaced by the 3D parcel. The 3D parcel is a volume of space on, above, or below the ground that defines and represents a particular array of rights, restrictions, or responsibilities. It can be an ownership right to an apartment unit or an easement in a 3D space such as a party wall.

Most of the cadastral data models such as the Core Cadastral Data Model, FGDC, and ArcGIS Parcel Data Model have been developed based on 2D land-parcels. ePlan and

LADM support 3D parcels to model 3D RRRs. However, it has not been fully exercised in ePlan (Cumerford, 2010). And, LADM does not use solid geometry (GM_Solid) to represent 3D parcels.

None of cadastral data models' geometrical representation is semantically enriched. Semantic enrichment reduces the ambiguities for geographic integration and geometrical inconsistencies (Kolbe, 2009). Well-known examples for these inconsistencies are 'flying' or 'drowning' buildings, when a Digital Terrain Model (DTM) and 3D building models from different sources are combined (Stadler & Kolbe, 2007).

Digital 3D cadastres can be used by different customers within multiple applications, provided a common information model could extend over the different users and applications. A semantically enriched 3D cadastral data model would then enable collaboration in heterogeneous environments.

The cadastral data models do not integrate physical counterparts with 3D legal objects (3D parcels). The required level of detail of physical information is dependent on the application. For example, land registries may require a simplified overview of the physical models (walls, ceilings, and roofs), while very detailed information (windows, doors, stairs, and pipes between walls) may be required in property management. Using LADM's external classes would not allow the users to define the level of detail of required information for a specific application. Table 3.4 summarises the specifications of the reviewed cadastral data models.

Table 3.4: Specifications of the data models

Specification	Core Cadastral Data Model	FGDC	ArcGIS Parcel Data Model	Legal Property Object Model	ePlan	LADM
Core objects	Person, Right, Parcel	Agent, Right and Interest, Parcel	Ownership, Encumbrances, Separated Rights	Person, Legal Property Object	Parcel, Document, Survey, Surveyor, Observation, Address, Point, Geometry	LA_Party, LA_RRR, LA_BAUnit, LA_SpatialUnit
Basic spatial unit	2D Parcel	2D Parcel	2D Parcel	Legal Property Object	2D Parcel	LA_Spatial Parcel
Other forms of spatial units	N/A	N/A	Vertical parcels	Every object will be treated as a separate Legal Property Object	BuildingFormatLot, VolumetricLot	Sketch-based, Text-based, Point-based, Line-based

Specification	Core Cadastral Data Model	FGDC	ArcGIS Parcel Data Model	Legal Property Object Model	ePlan	LADM
Reference documents	Transactions evidences, Mortgages	Deed, Aerial, photograph, Agreement, Mortgage, Satellite Image, Survey Notes	Deeds, Survey plans, Mortgages, Lease contracts	All legal Document	Title, Approval, Dealing, Any other legal documents	All documents providing legal and/or administrative facts
Applications	Valuation, Taxation, Security of land tenures, Spatial or physical planning	Model cadastral information , Basis for automating the legal elements	Development of parcel level management, Support parcel level functionality in the GIS environments	Facilitates the land administration system to be more extensible and scalable in terms of new legislations and land-related laws	Eliminate the current reliance on hardcopy or PDF plans, Improve the quality of plan data, Improve plan examination processing	Land administration applications

Specification	Core Cadastral Data Model	FGDC	ArcGIS Parcel Data Model	Legal Property Object Model	ePlan	LADM
Inclusion of other types of interests	N/A	Mineral rights, Oil rights, Grazing rights, Fishing rights, Development rights, Floodplains	Mineral rights, Oil rights, Grazing rights, Fishing rights	Biota rights, Mineral rights	N/A	Utility Network
Temporal aspects	Yes	Yes	Yes	Yes	Yes	Yes
Management & representation of stratified RRR	2D Parcel	2D Parcel	2D Parcel	2D Parcel	2D Parcel, VolumeGeom	LA_BoundaryFaceString (2D Parcel), LA_BoundaryFace (3D Parcel)
Semantic-level	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description
Physical objects	N/A	N/A	N/A	N/A	N/A	External databases

The proposed 3D cadastral data model will be utilised with the primary objects of the Core Cadastral Data Model (*Person*, *Right*, and *Parcel*) supplemented by the *Legal Property Object* concept. It also attempts to model the information of survey plans, such as those in the ePlan model, in a three-dimensional space. The proposed 3D cadastral data model will utilise the concepts and terminologies of LADM. However, it focuses on geometrical 3D spatial units and will model both legal and physical spaces together. It also supports temporal changes based on updating its spatial and descriptive information.

3.10 CHAPTER SUMMARY

In this chapter, six popular and important cadastral data models were reviewed and assessed. The aim was to understand how they manage stratified land rights, restrictions, and responsibilities and their physical counterparts. Ten criteria were developed for the assessment purpose. They helped to explore each data model in detail. The results were summarised in Table 3.4. Overall, it is concluded that the cadastral data models vary among jurisdictions since the applications and purposes of cadastres vary in each jurisdiction. Cadastral data models rely on the basic building block of a 2D land-parcel and have been developed based on the definition of a 2D land-parcel. Those that support 3D RRRs do not use solid representation and are not semantically rich for interoperability purposes. None of them integrate and mode physical counterparts of legal objects inside the model.

The proposed 3D cadastral data model will utilise the concepts of *Legal Property Object* model. Because, this model is not a land parcel-based data model and it a spatially referenced data model; hence, it enables the inclusion of all interests in land comprehensively and accommodate the increasing number of new interests on land. Using 3D geometries, semantics and integration of both legal and physical objects are the key consideration in the model.

The first three chapters of this thesis have considered the problem of current cadastres in terms of managing stratified interests, needs for developing 3D cadastres, need for developing a 3D cadastral data model, and advantages and shortcomings of current cadastral data models in order to manage stratified RRRs. The next chapter describes the development of the project's research design. It returns to the underlying research problem and explains how the findings of background chapters were used to generate a research hypothesis. The research methodology are outlined and justified.

CHAPTER 4 – RESEARCH DESIGN

4 RESEARCH DESIGN

4.1 INTRODUCTION

The previous chapters described the context of the research in relation to the areas of cadastres, data modelling, 3D cadastral data modelling, and comparison of current cadastral data models. This chapter outlines the design and methods that were used to answer the research questions and achieve the research aim (Section 1.5). The first part of the chapter investigates the conceptual research design by reviewing the research problem and questions, and then explores the possible research methods available to answer these questions. The chosen research approach is then justified and the final research design presented. The research methods utilised for the development of the final model are detailed and issues relating to validity are discussed.

4.2 THE SCIENTIFIC METHOD

The scientific method is the process by which scientists, collectively and over time, take a series of steps to ask and answer scientific questions by making observations and doing experiments about the research project (Goldhaber & Nieto, 2010).

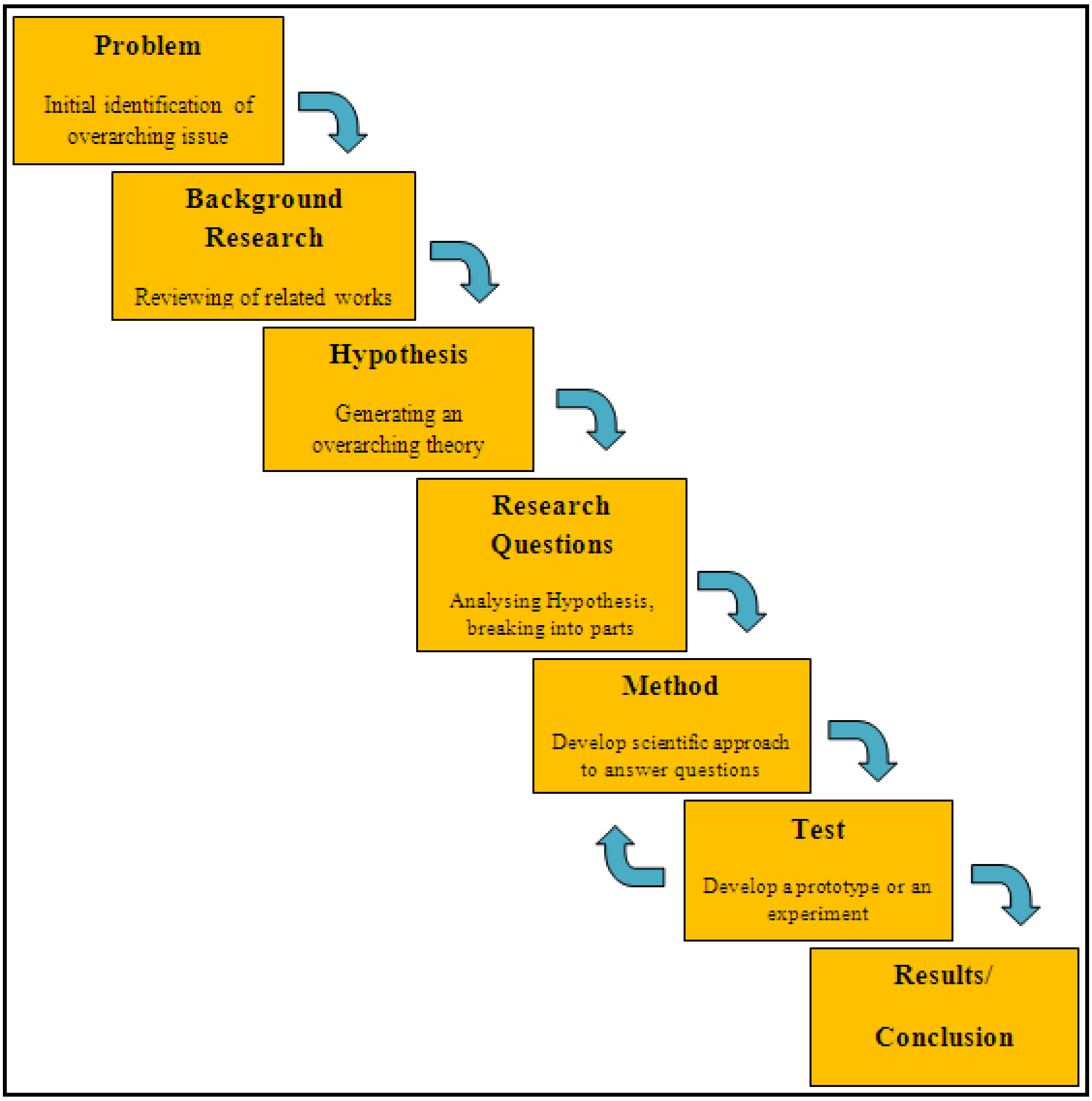


Figure 4.1: The scientific method was used to guide the project design

The scientific method, modernised by Kuhn (2012) involves identifying a problem, conducting background research, generating theories or hypotheses, analysing hypothesis by breaking hypothesis into research questions, creating alternative solutions or developing scientific approach to answer questions (method), test the hypotheses by building a prototype or by doing an experiment, redesigning the method as necessary, analysing the results and drawing conclusion (Figure 4.1). In this scientific method, the hypotheses are applied to more specific research questions, which lead to the definition and testing of measurable variables. This deductive approach provides a framework for the entire study and an organising model for the research questions and data collection procedures

(Creswell, 2009). Each of these stages and their application to the research are now discussed.

4.3 PROBLEM

The first stage of the scientific method involves clearly articulating the problem. It should identify and provide definitions of the subject. As stated in the introductory chapter, the overarching research problem was articulated as:

> In dense urban populated areas, current land administration systems use 2D cadastral data models which:
>
> a) do not support 3D data do not efficiently facilitate representation and analysis of 3D data.
>
> b) are not semantically enriched
>
> c) do not incorporate physical objects.
>
> Therefore they cannot adequately manage and represent the spatial extent of stratified land rights, restrictions and responsibilities (RRRs).

Where,

> 'Dense urban populated areas' are mostly city centres in which 3D developments such high-rise and multi-occupancy residential and commercial buildings, and underground facilities (tunnels and utility networks) are common, and as a result, different rights (RRRs) are intersected together in a particular extent of land.
>
> '2D cadastral data models' are land parcel-based data models. Land parcels are the basic building blocks of the most cadastral data models. A land parcel defines the ownership boundary of a piece of land. In the land parcel-based cadastres, all ownership information in a particular extent of land (even stratified rights) is projected on the land parcel (See Chapter 2).
>
> '3D data' represents 3D legal and physical objects (See Chapter 6).

‘Physical objects’ (or physical models or physical information) are physical counterparts of legal objects. They are a representation of related city objects such as buildings, tunnels, utility networks and etc (See Chapter 2).

‘Semantically enriched data models’ are data models in which semantics are used to describe all elements of the data models including classes, attributes, associations, as well as geometric classes of spatial objects (See Chapter 6 and 7).

4.4 BACKGROUND RESEARCH

The second stage of the scientific method involves conducting background research, which refers to accessing the collection of previously published and unpublished information about a particular topic of interest and it is one of the important steps of all good research investigations (McCormac et al., 2012).

In the context of this research, background research may include some combination of conducting a review of the 3D cadastres and data modelling literatures, learning from the experience of others rather than blunder around and repeat the potential mistakes, obtaining copies of standards and documents with regards to data modelling and land administration, interviewing data modellers, registered surveyors, registrars, land lawyers, visitors and industry partners who may have knowledge about 3D cadastres and 3D cadastral data modelling.

4.5 FORMULATING THE HYPOTHESIS

The third stage of the scientific method involves the proposal of a hypothesis that best explains why the problem is occurring or how it might be solved. In the context of this research, described in the Chapter 2, cadastres are regarded as the engine of land administration systems to help manage interests in land and its resources. 3D developments of land are common and put enormous pressure on current land administration systems, which are equipped with the cadastres that are only able to maintain 2D spatial information. The background chapters were structured around the problem of current cadastres, needs for 3D cadastres, and needs to explore the scope and elements of 3D cadastres by developing 3D cadastral data models to better manage stratified land rights, restrictions, and responsibilities (RRRs). With this in mind the research hypothesis was generated:

> A 3D cadastral data model will improve current land administration systems to better manage stratified (3D) land rights, restrictions and responsibilities in the dense urban populated areas.

Where,

> 'A 3D cadastral data model' is a cadastral data model, which is based on 3D parcels and provides:
>
> - exploration of the different elements of 3D cadastres (classes and attributes) and how they are arranged (associations, cardinality, and constrains)
> - templates and practical guidelines for land surveying professionals
> - simplification of the process of implementing 3D cadastres
> - promotion of standards and a common language within the land administration user communities
> - foundation of a 3D cadastre database
> - facilitation of the exchange of data and the integration of similar datasets, and ease data sharing and interoperability
> - understanding data requirements of involved parties.
>
> 'A Land administration system' in the traditional context involves the process of determining, recording and disseminating information about the tenure, value and use of land when implementing land management policies (UNECE, 2005).
>
> 'Stratified land rights, restrictions and responsibilities' are rights that are over or under other rights on a particular extend of land. RRRs can be represented three dimensionally (3D) and they are not overlapped horizontally and vertically.

4.6 ARTICULATING THE RESEARCH QUESTIONS

Using hypotheses to develop a set of research questions is the fourth stage of the scientific method. By answering the research questions the appropriateness of the hypothesis can be deduced. In the context of this research the background investigations resulted in a number of questions that relate directly to the hypotheses. The questions are based around the 3D cadastral data modelling and consider how it might be used to explore the 3D cadastre. They research questions are:

- What is a 3D cadastral data model? How can it help to explore and understand 3D cadastres?

To answer these questions a literature review is performed on cadastres and data modelling (Chapter 2), as well as the role of 3D cadastral data models to explore 3D cadastres and manage stratified RRRs (Chapter 2). In chapter 3, current cadastral data models are compared to find the requirements of the 3D cadastral data model.

- Why cannot current cadastral data models manage to stratify RRRs efficiently? Is there a need to develop a new data model to support the concepts of 3D cadastre?

To answer these questions the most popular cadastral data models are investigated and compared in order to identify their deficiencies and utilise their experience to develop a new data model for better management of stratified RRRs. This is described in Chapter 3.

- What are the data sources of the 3D cadastre? How many data sources are there to provide information for a 3D cadastral data model?

To answer these questions one case study is undertaken in Chapter 5 to identify the type of data sources and the type of data those data sources can provide. The case study also helps to understand the current process of 3D property registration.

- What should be represented in the 3D cadastre? What are the business requirements for developing a 3D cadastral data model? What type of objects, attributes should be recorded in a 3D cadastral data model? How many RRRs do exist and should be considered in a 3D cadastral data model? How many components should a 3D cadastral data model have? How should a 3D cadastral data model provide the need of the multi-purposes 3D cadastre?

The research strategy to answer these questions is to assess the needs of user communities. Thus, a business analysis is performed based on the information gathered from the 3D cadastre questionnaire, which was conducted by the Intergovernmental Committee on Surveying and Mapping (ICSM) members to define the requirements for 3D cadastres. In addition, a number of interviews and discussions have been conducted by the project's industry partners including Land Victoria (Victoria's land registration department), VEKTA (surveying company), Alexander Symonds (surveying company), and ICSM members to have further input in the business analysis. The basic objectives of business analysis involve: gathering and defining basic objects and data elements; describing the information about the data elements and the relationships among them; and comprehensively documenting all of the requirements for developing the 3D cadastre. This is described in Chapter 6.

- What are the requirements to implement the 3D cadastral data model? What type of geometrical objects should be considered in the 3D cadastral data model being able to represent stratified RRRs?

- How can a data model be designed and developed to accommodate the requirements of 3D cadastres and interactions between all legal and physical objects?

To answer these questions, possible implementation methods are discussed in Chapter 7 and 8. In this regard, XML schemas are developed to be able to accommodate the 3D cadastral data model information. The schemas are populated for a case study and presented in a three dimensional platform.

4.7 DESIGNING THE EXPERIMENTS (METHOD)

Designing experiments to answer the research questions is the fifth stage of the scientific method. This involves designing a number of experiments to answer the questions listed above. In terms of answers, each question can be placed into one of two categories: they either demand qualitative or quantitative responses. For example, the question: 'How many

RRRs do exist and should be considered in a 3D cadastral data model?' is quantitative in nature and a numerical answer is the desired response. However, the question: 'What are the business requirements for developing a 3D cadastral data model?' is qualitative in nature and the narrative of the answer would be of more value than a single numerical response. For this reason both qualitative and quantitative experimental methods would be required to answer all the research questions. An overview of each of these methodologies is now given.

4.8 QUANTITATIVE METHODS

Quantitative methods are methods that use experiments to produce numerical outcomes, which can then be used to validate hypotheses. The focus in quantitative methods is on "measurements and amounts (more or less, larger or smaller, often or seldom, similar or different) of the characteristics displayed events that the researcher studies" (Thomas, 2003). Measurable variables, defined within the research questions, are at the core of this method. They must be defined, collected through experiments, analysed and then presented. Quantitative methods often incorporate large sample sizes in experiments and subsequently allow for the use of statistical methods.

In the context of this research, quantitative methods could be used to answer the 'how many…' questions listed above. For example, how many RRRs do exist and should be considered in a 3D cadastral data model? A study of existing cadastres and cadastral data models, which collects variables on amounts of objects, attributes, enumeration, and legislation, would provide the necessary data. A quantitative method is also used for evaluating the proposed data model. The evolution is based on rating the data model against various data modelling quality factors.

4.9 QUALITATIVE METHODS

A qualitative method is characterised by the collection and analysis of textual data (interviews, surveys, observation), and by its emphasis on the context within which the study occurs (Borrego et al., 2009). Qualitative methods are undertaken to understand how and why certain phenomena are occurring. The researcher describes the characteristics of the events being studied. Qualitative research differs from quantitative research: the data it produces cannot be statistically analysed or graphed. It produces descriptive data relating to the events being studied. While the outcomes of quantitative methods can be conclusive, qualitative methods tend to be merely suggestive. Well-known techniques for qualitative methods include case studies, personal experience, narrative research, action research and observation (Denzin & Lincoln, 2011).

The strength of the qualitative methodology lies in its focus on specific events and its emphasis on words rather than numbers (Maxwell, 1992). It enables a much richer understanding of individual events and the contexts in which they occur. It helps develop different lines of enquiry and data collection (Flick, 2009).

Qualitative research is often criticised by the 'hard' sciences such as physics and chemistry for its 'soft' approach and its inability to strictly adhere to scientific methods (Yin, 2003). It has been described as merely a tool for stand-alone descriptions of phenomena and as preliminary research to the real research of hypotheses and statistic testing (Benbasat, 1984). However, other authors argue that qualitative research has similar standards of credibility when used properly and that frameworks now exist, which provide both a rigorous and scientific approach (Lee, 1989; Krefting, 1991; Yin, 2002).

In the context of this research, qualitative research methods could be used to answer all of the 'How should…?' 'Why do…?' or 'What are …?' questions. For example: What are the business requirements for developing a 3D cadastral data model? What type of objects and attributes should be recorded in a 3D cadastral data model? Qualitative methods would facilitate greater understanding of the advantages and shortcomings of the existing cadastral systems in terms of managing stratified RRRs. The context in which they exist, their strengths and weaknesses could all be assessed and used to inform the design of new systems (data model) (Bennett, 2007).

4.10 USING CASE STUDY

There are many types of qualitative research; however, consideration is now given to the type highly applicable in this research: the 'case-study' approach. Case studies examine a trend in its natural setting and use multiple data collection methods along with a small number of entities (Benbasat et al., 1987). Case studies focus on individual examples and on processes and relations, rather than a one-time cross-section of individuals (Feagin et al., 1991). For each individual case study a number of experimental and non-experimental research techniques might be employed (Bordens & Abbott, 2008). Most importantly, they can be used to build theory and arrive at generalisations (Evans et al., 2011). Case studies rely upon multiple sources of evidence (Yin, 2003). Examples include interviews, surveys, legislation, strategic plans, management reports, operational procedures, brochures and independent reports relating to the public and private organisations.

The case study approach is appropriate when the phenomenon under study is not readily distinguishable from its context and when there is a need to define topics broadly and rely on multiple rather than singular sources of evidence (Yin, 1993).

Thus, the case study can provide a useful tool across many disciplines including sociology, political science, psychology and information management (Yin, 2002). On a practical level, it is used in public administration research, community planning, city and regional planning and information systems planning (Yin, 2002). In the case of information systems and engineering it provides a useful approach for investigating how people, processes and technology interact during development and use.

Yin (1993) makes a distinction between descriptive, explanatory and exploratory case studies. All can be single or multi-case in nature. ‘Exploratory’ case studies are flexible: no earlier model is used as a basis for the study, usually because the researcher has no alternative. By their very nature exploratory case studies discover new theory. The hypotheses are developed progressively and often after completion of data collection. These studies are sometimes criticised for lacking rigor and structure. On the other hand, ‘descriptive’ case studies observe and describe what trends exist in the phenomena being studied. Williamson and Fourie (1998) show how ‘exploratory’ and ‘descriptive’ case studies are a useful framework for describing and classifying cases. The resulting hypotheses explain cause–effect relationships. ‘Explanatory cases are best suited to causal studies. In very complex and multivariate cases, the analyses rely upon pattern-matching techniques.

The field of land administration advocates the use of case studies. Many recent PhD theses in land administration design and planning have used this approach (Ting, 2002; Steudler, 2004; Stoter, 2004; Dalrymple, 2005; Warnest, 2005; McDougall, 2006; Bennett, 2007; Kalantari, 2008; Hespanha, 2012). Williamson and Fourie (1998) recommended case study methodology for more rigorous research of cadastral reform. They argued that a useful technique was to employ a case study approach, linking human issues (in an anthropological context) with the existing knowledge base. Steudler (2004) made similar recommendations. He suggested that while different countries have very different land administration arrangements some general indicators do exist. These can be used compare systems, identify underlying problems and recognise benefits at a local and practical level. Indeed the case study approach is the only way to understand the broad field of land administration: cases help to address contextual conditions and not just the overarching phenomenon of the study (Yin, 2003). Any study dealing with land administration that is not informed by an understanding of the contextual conditions such as economic, political and social forces is very much weakened.

In the context of this research, case studies, particularly the 'descriptive' form, appeared highly relevant for a number of reasons. Firstly, they would allow for analysis and description of current practice of 3D property registration. The data collected from subdivision and architectural plans would enable the creation of a more rigorous framework for the classification and management of data modelling objects and attributes. Secondly, as outlined by Yin (1993), there is a need to define topics broadly and not narrowly: land interests (RRRs), their management and impact were seen as very broad. Thirdly, case studies allow multiple sources of evidence to be studied. Additional data would be gathered from a range of sources including interview material, legislation, government policies and literature. Fourthly, the management of stratified RRRs could be studied in their normal settings. This provides the opportunity to learn from current approaches and practice (Benbasat et al., 1987; Maxwell, 2005). Fifthly, as already discussed, qualitative methods enable 'how' and why' questions to be answered (Benbasat et al., 1987; Yin, 2002). Sixthly, the case study approach provides a system for analysing and classifying stratified RRRs and 3D cadastral objects. Consideration is now given to mixed methodologies, an emerging form of research design.

4.11 MIXED METHODOLOGIES

Generally, it is difficult to answer research questions through any single qualitative or quantitative approach (McDougall, 2006). While a case study approach addresses the ‘why’ and ‘how’ questions, a quantitative approach can address ‘how many’ questions. However, an appropriate approach is needed, so that it would allow combining these seemingly unrelated methods. During the 1990s, the benefit of combining parallel methods had been recognised in both theory and practice and numerous explanations of mixed method research emerged in the design literature (Frechtling & Westat, 1997; Tashakkori & Teddlie, 1998; Johnson & Onwuegbuzie, 2004; Creswell, 2009).

Mixed methods can design and incorporate techniques from both the qualitative and quantitative research traditions, and can answer research questions that could not be answered otherwise. Therefore, mixed methods are superior to a single approach for a number of reasons: they provide stronger inferences and allow the opportunity of presenting a greater diversity of views. The approach continues to grow in popularity (Tashakkori & Teddlie, 2010). Furthermore, most research practices now lay on the continuum between qualitative and quantitative analysis. However, the mixed methods approach is not without its problems and care must be taken in the integration and interpretation phases of research (Bryman, 1992). However, when properly combined the mixed methods approach is powerful (Bennett, 2007).

Perhaps the most important consideration in undertaking a mixed method approach is the way that qualitative and quantitative methods are combined (Brannen, 1992; McDougall, 2006). As suggested by Creswell (2009), usually one approach will be given supremacy. Bryman (1988) offered three possible scenarios: quantitative over the qualitative; qualitative over the quantitative; and equal weight given to qualitative and quantitative. Where quantitative is more heavily weighted, qualitative studies are taken prior to or after the main quantitative study. It may form the basis for development of the research instrument or clarification of quantitative data. Where qualitative is more heavily weighted, a quantitative study can provide background data to contextualise small intensive studies; test hypotheses derived through qualitative methods; or provide a basis for sampling and comparison. Where quantitative and qualitative are given equal weighting the two studies are considered as separate but linked, and can be performed simultaneously or consecutively. The processes may be linked at various stages in the research process and then integrated to formulate the final outcomes.

In the context of this research a mixed method of qualitative and quantitative studies was considered the most appropriate. Justification is now provided. Firstly, in land administration research, mixed methods research has gained in popularity. Warnest (2005) and McDougall (2006) combined qualitative case study approaches with more quantitative questionnaires. Secondly, the research questions identified in this research are difficult to answer through any single approach. A qualitative approach was deemed as the most suitable approach to addressing the 'why do…' and 'how should…' questions. A mixed method approach would enable both types of questions to be answered and would consequently test the hypothesis. Thirdly, a mixed method approach would minimise the weaknesses of either single approach: the qualitative case study approach would provide the opportunity to investigate the context and requirements of users in greater depth, whilst a quantitative study of cadastres would enable a broad understanding of the existing arrangements in practice (Bennett, 2007).

4.12 PRACTICAL IMPLEMENTATION

Mixed methodologies are justifiable at a theoretical level; however, further discussion is needed regarding their application to this research.

The original research problem focused on the 3D cadastral data modelling elements (classes, attributes, associations, cardinality, and constrains). Two perspectives were required: a data-oriented perspective, which considers user needs; and model-oriented perspective, which consider data-modelling techniques and requirements achieved from comparison of current cadastral data models and existing standards. Each perspective can include a qualitative and quantitative study. Since there are no any notable numerical studies in the field of the 3D cadastral data modelling except in evaluation of the proposed data model, qualitative studies are mostly used to answer the questions in this research. Figure 4.2 shows the methods used in this research.

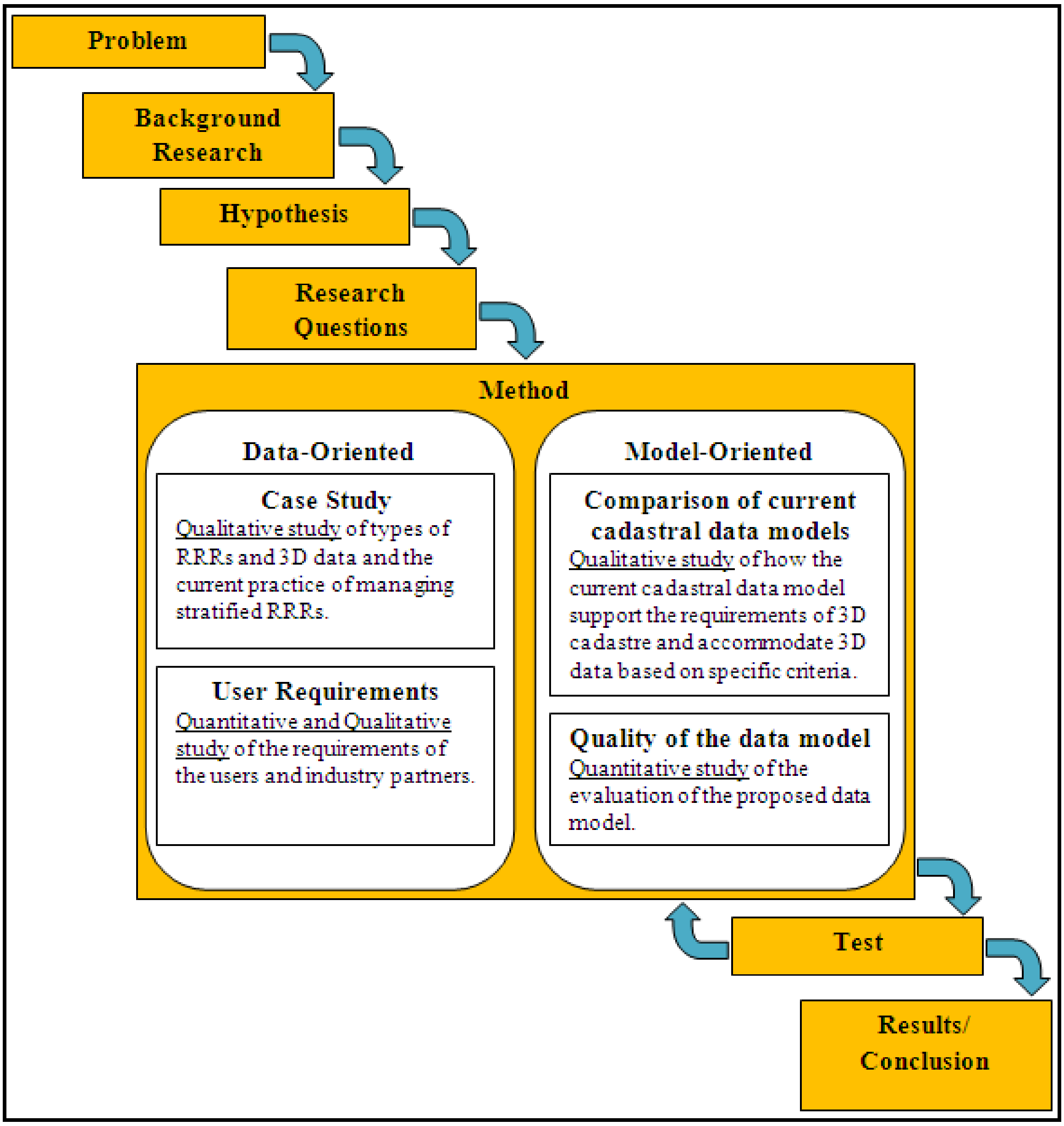


Figure 4.2: The research methodology in practice

Therefore, the research design incorporates information achieved from case studies and user requirements analysis in data-oriented perspective and modelling requirements achieved from comparison of the current cadastral data models and from existing data modelling standards and documents from a model-oriented perspective. All studies undertaken were considered equal in weight. According to Bryman (1992) this meant that the studies could be considered as separate but linked and could be performed simultaneously or consecutively. The separate data-oriented and model-oriented perspectives are now considered.

4.13 DATA-ORIENTED PERSPECTIVE

What are the 3D cadastral data model elements in terms of classes, attributes, associations, cardinality, and constrains? The case study and business requirement analysis address this question from the perspective of data that is required in the 3D cadastre.

To select a case study, firstly the case study area or a jurisdiction should be selected. The selection of the jurisdiction was based upon a number of criteria. Firstly, the jurisdiction needed to maintain the 3D ownership registration. Secondly, the jurisdiction needed to have an easily accessible legal system to study legal documents of 3D ownership registration. Thirdly, the jurisdiction required accessible cadastral mapping and registration systems. Fourthly, the jurisdiction needed to be sufficiently developed in terms of technological capacity and spatial information initiatives. Fifthly, the jurisdiction needed to appreciate implementation of digital 3D cadastre. Finally, the jurisdiction needed to be accessible to the researcher.

Melbourne, the capital and most populous city in the State of Victoria, Australia, was the chosen jurisdiction. While some Western European jurisdictions matched the criteria, Melbourne was local to the researcher and would offer easy access. One case study was chosen in Melbourne for further investigation. More details regarding Melbourne and the case study are provided in the following chapters.

The ‘qualitative’ component of the data-oriented study required an analysis to discover which objects should be considered in the 3D cadastral data model. This enabled a number of the qualitative research questions to be answered. Firstly, existing legislations that allow 3D ownership registration were reviewed. The aim was to understand the basis of practical implementations. Then, the volume folios (title information) and subdivision plans of each case study were analysed with a view to identifying every piece of information. This was the fastest and most comprehensive way to identify the majority of information required for consideration in 3D cadastre and consequently in the 3D cadastral data model.

A case study site was chosen: an underground car park, which traverses its surrounding parcels. This was considered to be a good example of a 3D property and would also fit with the time and resource limitations of the researcher.

A two-stage process was undertaken for the case study. First the case study was visited and inspected, and matched with its subdivision plan (observation). Also, several meetings were arranged with the surveying company that subdivided the case study to further clarify the methods of managing and representing stratified RRRs in the current system.

The second stage focused on the 3D visualisation of the case study to understand how RRRs will be represented based on the available information. Therefore, it was possible to discover what additional information is needed to better represent the current legal situation of a 3D property and what are the shortcomings of the current 3D registration process in terms of being able to visualise stratified RRRs. Autodesk's AutoCAD Map 3D and Trimble SketchUp were used for this purpose.

The outcomes of this study were used to answer a number of the qualitative research questions: for example, the underlying reasons for how stratified RRRs are managed and represented in the current system and what information should be considered in the 3D cadastral data model.

Furthermore, 'quantitative' and 'qualitative' component of the data-oriented study required a business requirement analysis. The aim was to analyse the user requirements. This study helped to understand what users expect from a 3D cadastre. The business requirement analysis conducted by the members of the Intergovernmental Committee on Surveying and Mapping (ICSM) who are cadastre and land administration professionals. A number of professionals mostly from project's industry partners were interviewed.

Business analysis is an important step defining requirements in the data modelling and database development cycle. This step is conducted by interviews and discussions with both the developers (producers) and end users. The basic objectives of business analysis involve: gathering and defining basic objects and data elements; describing the information about the data elements and the relationships among them; and comprehensively documenting all of the requirements (Simsion & Witt, 2005).

The research strategy for determining the requirements for the 3D cadastre was to assess the needs of user communities. This information was summarised below (Table 4.1). It is based on: the survey conducted by the members of the Intergovernmental Committee on

Surveying and Mapping (ICSM) of Australia/New Zealand (ICSM, 2007); the discussions in the collaborative research workshop on 'Land and Property information in 3D', at the University of Melbourne, Australia, 2011; and from the observations in the '2nd International Workshop on 3D Cadastres', Delft, The Netherlands, 2011. The results are explained in Chapter 6.

Table 4.1: The needs of user communities form a 3D cadastre

User Needs	Requirements
Digital 3D cadastre	To have 3D index map and 3D titling system
Functional 3D cadastre	To have a functional multi-purpose 3D cadastre
3D data	To provide 3D data for implementation purposes
Various data type	To consider various data type in the 3D cadastre
Interest holder information	To maintain interest holders and descriptive information in the 3D cadastre
3D primitives (geometry)	To have 3D primitives to support 3D representation, analysis, and storage
Accuracy and reliability 3D cadastre	To have accurate and reliable information for 3D titling system
Temporal 3D cadastre	To have temporal information of land transactions and track updates

At the completion of the data-oriented studies an understanding had been gained of how stratified RRRs are now managed and represented and what information is needed to consider in the 3D cadastral data model. However, as stated in the research design, the issues relating to managing stratified RRRs through the 3D cadastral data model go beyond data and data types but data modelling techniques and advantages of current cadastral data models must also be considered. The model-oriented study provided this perspective.

4.14 MODEL-ORIENTED PERSPECTIVE

How should a 3D cadastral data model be developed to consider the requirements of 3D cadastres? Why cannot current cadastral data models manage stratify RRRs efficiently? Is there a need to develop a new data model to support the concepts of 3D cadastre? The model-oriented study would address this question from the perspective of data-modelling techniques.

Since land administration requirements differ among the different jurisdictions, various cadastral data models have been developed around the world. However, these data models cannot adequately manage and represent the spatial extent of stratified RRRs. Most of the current cadastral data models have been influenced by a very broad understanding of 3D cadastral concepts. Six cadastral data models are assessed in this research. They are:

- The core cadastral data model (Henssen, 1995)
- FGDC Cadastral Data Content Standard for the National Spatial Data Infrastructure (FGDC, 1996)
- ArcGIS Parcel Data Model (Meyer, 2001)
- The Legal Property Object Model (Kalantari et al., 2008)
- ePlan (ePlan, 2010)
- ISO 19152, Land Administration Domain Model (LADM) (ISO19152, 2012).

These data models are the most popular cadastral and land administration data models that were found through literature and background research. They are assessed and compared based on selected criteria. The aim was to analyse how they manage stratified RRRs and meet user requirements. What data-modelling techniques do they use to support 3D data?

The criteria were selected in a way to be able to assess the data models from different aspects and provide information how they manage stratified RRRs. Table 4.2 summaries the criteria used for comparing the above-mentioned cadastral data models.

Table 4.2: Criteria for comparing current cadastral data models

Criteria	Description
a) Core objects	What are the core objects of the data model? (Person, Right, Spatial Unit, Parcel)
b) Basic spatial unit	What are the basic spatial units of the data model? (2D parcel, 3D parcel)
c) Other forms of spatial units	Does the data model have other forms of spatial unit? (Text-based, Point-based)
d) Reference documents	What are the data sources? (Survey plans, Architectural plans, Titles, Deeds, Mortgages)
e) Applications	In what applications can the data model be used for? (Registration, Taxation, Valuation, Planning, etc.)
f) Inclusion of other types of interests	Whether or not other types of interests are considered in the data model? (Utility network rights, Biota rights, Mineral rights)
g) Temporal aspects	Whether or not temporal aspects of interests are considered? (Time the right is created or terminated)
h) Management and representation of stratified RRRs	How does the data model render stratified RRRs? (Projection on the ground level, 3D primitives)

i) Semantic-level	At what level does the data model support semantics? (Class-level, Attribute-level, Geometry level)
j) Physical objects (physical counterparts)	How does the data model support the physical counterparts of legal objects? Internally (in the model), Externally (external databases)

This process resulted in a very strong understanding being formed of the status of current cadastral data models in terms of managing stratified RRRs. It enabled an understanding to be gained of important cadastral data models, their advantages and disadvantages for developing a new data model.

Furthermore, the following standard documents were used as references to evaluate the data models and apply the concepts in development of a 3D cadastral data model.

- ISO 4217:2008, Currency names and code elements
- ISO 19103:2005, Geographic Information-Conceptual Schema Language
- ISO 19105:2000, Geographic Information-Conformance and testing
- ISO 19107:2003, Geographic Information-Spatial Schema
- ISO 19108:2002, Geographic Information-Temporal schema
- ISO 19111:2003, Geographic Information-Spatial referencing by coordinates
- ISO 19103:2005, Geographic Information-Conceptual Schema Language
- ISO 19152:2012, Geographic Information-Land Administration Domain Model (LADM)

The final outcome of this thesis (3D cadastral data model) took place with Enterprise Architect software and described in Unified Modelling Language (UML) schemas.

4.15 PROCESSING RESULTS AND MAKING CONCLUSIONS

The sixth and final stage of the scientific method involves testing and analysing the results, answering the research questions and consequently making conclusions about the hypothesis (Figure 4.3).

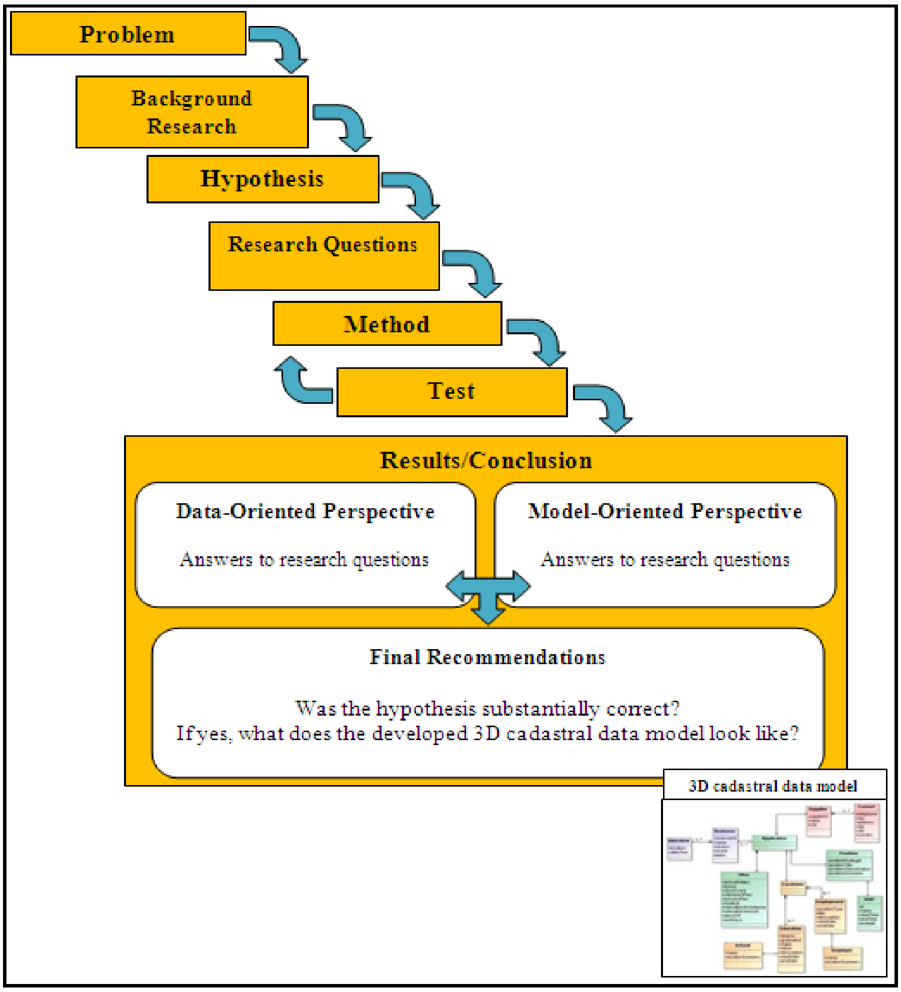


Figure 4.3: The result and conclusion stage of the scientific method

First, the results from the various research studies were used to answer related research questions. The results of the case study and answers to the research questions are presented in Chapter 5. Second, the answers were tested or checked. Using two perspectives (data-oriented and model-oriented) meant each could be used to test the results of the other. By comparing the results from the two perspectives, ideas were tested and differences and agreements were identified. Areas of agreement could be considered points of truth. Areas of disagreement could be considered unresolved: no certainty had prevailed. After this analysis the resulting set of robust answers were compiled and the hypothesis had been tested: it was now clear which ideas and principles would be used to develop a 3D cadastral data model which consequently assisted in managing stratified land rights, restrictions, and responsibilities. This discussion is undertaken in Chapter 9. Finally, the answers to the research questions were assessed to develop a new 3D Cadastral Data Model (3DCDM) for managing stratified property interests. The components of the core cadastral data model (Henssen, 1995) and concept of Legal Property Object (Kalantari et al., 2008) were used as a basis and all new components, concepts, and principles were included. This new framework and its components are introduced in Chapter 6 and 7.

4.16 LIMITATIONS AND ETHICAL CONSIDERATIONS

While the research design has been fully justified in this chapter, it is worth noting a number of limitations. These are predominately time and resource constraints. Firstly, no case studies were conducted outside Australia. An in-depth case study of a Western European or North American jurisdiction would have provided additional validation of the Australian case study results. Many Western European (e.g. Netherlands) jurisdictions have started 3D cadastres. Secondly, no in-depth studies of emerging users and land information providers were conducted. Emerging users include the utility network authorities, developers, real estate agents, local councils, emergency services, property management services, and ordinary people (interest holders). Industry bodies could have been surveyed to gain an understanding of information needs. Individual organisations could have been consulted to assess any innovative solutions for managing stratified RRRs. The users are outside the circle of cadastre and land administration professionals should be considered in this investigation, however in this stage, as mentioned before, land registries, surveyors, and related organisations such as ICSM are amongst the intended users.

Since every jurisdiction could have its own cadastral data model, a few of them were selected for the comparison purposes. The reason was they were the most popular cadastral data models that were accessible and available in the English language.

Another efficient methodology for developing a new data model can be an incremental approach with a continuous expert reviewing during a period of time as Lemmen (2012) has designed in his PhD work. This approach does not work in this research, because of the time restriction.

Perhaps these limitations could be used as starting points for future research in the area. In relation to ethics, because no responses from people were directly analysed or published throughout the research ethical considerations were not relevant.

4.17 CHAPTER SUMMARY

This chapter fully outlines and justifies each component of the research design. The scientific method was used to guide the design process. The first stages involved developing the research problem and hypothesis, using background research. The research hypothesis led to the creation of a number of research problems, all of which needed to be answered in order to test the hypothesis. A mixed methodology involving both qualitative and quantitative studies was required to answer the questions. The data-oriented and model-oriented perspectives were also required to answer the range of research questions. Together, the results from the research and case studies would be used to test the appropriateness of the hypothesis and to generate elements and components of a new 3D cadastral data model, one capable of managing stratified interests in land. The following chapters provide the results of studies undertaken in accordance with the research design.

CHAPTER 5 – 3D PROPERTY REGISTRATION: AUSTRALIAN CASE STUDY

5 3D PROPERTY REGISTRATION: AUSTRALIAN CASE STUDY

5.1 INTRODUCTION

The aim of this chapter is to understand and recognise the cadastral elements and the current practice of 3D property registration using a case study approach in State of Victoria, Australia. The case study is an underground car park that traverses a number of land parcels and buildings. The country profile and discussion of Australia's and Victoria's cadastral systems are explained in this chapter.

5.2 AUSTRALIAN CADASTRAL SYSTEMS

5.2.1 Country Context

Australia is the largest island continent in the world, with a total area of over 7,600,000 sq km, lying south of the Equator between the Indian and South Pacific Oceans. Much of the interior of the country is flat, barren and sparsely populated. The population is approximately 22 million, with a growth rate of about 1.4%. The majority of the population (85%) resides in urban areas along the east and south-eastern coastline and fertile plains (ABS, 2013).

Australia's federation, Commonwealth of Australia, was formed in 1901 with six states: New South Wales (NSW), Queensland (Qld), South Australia (SA), Tasmania (Tas.), Victoria (Vic.), and Western Australia (WA) and two Territories: the Australian Capital Territory (ACT) and the Northern Territory (NT). Each state and territory has its own parliament. In most respects these two territories function as states, but the Commonwealth Parliament can override any legislation of their parliaments. By contrast, federal legislation overrides state legislation only in areas that are set out in the Australian Constitution (http://australia.gov.au).

5.2.2 Institutional Framework

The Federal Government has powers over defence, foreign affairs, trade and commerce, taxation, customs and excise duties, pensions, immigration, postal services, and telecommunications services. Other powers are the responsibility of state and territory governments, such as police, health, education, state public transport, town and planning and land administration (cadastral system and land registration) (Kalantari, 2008).

Even though there is considerable commonality, each state and territory has significant idiosyncrasy and complexities in its law governing land and the cadastral system. Within a national momentum to privatise government activities and agencies, land administration has tended to remain a government responsibility (Dalrymple et al., 2003).

As a federation of states, Australia maintains centralised land administration offices in each jurisdiction. There is no prescribed organisational structure common to all states; land administration is a state government responsibility performed under a range of government departments such as Environment, Planning, Lands or Land Administration.

Embedded in these departments are the State's digital cadastral map, land registry and titles offices, Crown lands management offices, Surveyors Board, and business units for land information and resources. Combinations of these services can be found in each state, integrated through sharing agreements. Today this is assisted by the computerisation of spatial and non-spatial information. A consortium of all states and the Commonwealth, called the PSMA Australia Ltd (Public Sector Mapping Agencies) (http://www.psma.com.au/), produces national digital cadastral map products comprising about 10.2 million land parcels (Dalrymple et al., 2003).

5.2.3 Australian Cadastral System

Each state and territory of Australia operates separate land administration and cadastral system. Cadastres have played a significant role in shaping Australia's development. Initially they provided registration of ownership for land settlement. Then, by providing security for land transfers, they assisted in the establishment of a successful and complex land market. The cadastral systems have recently evolved into comprehensive instruments for assisting economic, environmental and social decision making. This is shown in broadening land tenure arrangements, recognition of traditional Aboriginal land rights, and the use of new technologies to integrate cadastral information as a foundation of spatial information systems (Dalrymple et al., 2003).

The cadastral systems in Australia are historically based on registering land transactions generated by a land market. The second role of the cadastral system is to support the registration of land for legal ownership, registering the rights, restrictions and responsibilities pertaining to land through precise surveying methods regulated by government licensing. Although cadastral systems vary across the nation, the integrity of each system is consistent allowing the core spatial data set in spatial data infrastructures to play a fundamental role in broader land administration activities. Computerisation of spatial and textual data establishes the cadastre as an integral tool in many areas. These include facilitating (Williamson, 2003):

- in a legal capacity, the registration of ownership of land
- in a fiscal capacity, valuation of land sales and taxation
- more widely, in multipurpose functions in land management and planning for local government, emergency response, Australian Bureau of Statistics data capture, environmental risk assessment, and business planning.

Cadastral systems basically are created by surveying land parcels in the field, and recording the corresponding land ownership titles in the land registry. There is generally a 1:1 relationship between these two main units, that is each land parcel is related to one land ownership entry in a folio in the land register (Williamson, 2003).

The term ‘property’ is used by local councils that maintain property records for their own planning and rating purposes. A property has one street address, but can consist of one or many, normally adjacent, parcels owned by the same landowner. In probably 90% of the cases, however, a property consists of one parcel only. While the land ownership title is of interest to the land registry, the use of the term ‘property’ reflects the different needs of the local councils and utilities and is not a formal entity of the cadastral system. Buildings are part of the property records and are recorded by the local councils as well (Williamson, 2003).

5.2.4 Components of Australian Cadastral System

Victoria, the smallest, but the most densely populated and urbanised State of Australia, has achieved a considerable success in developing cadastre and land administration system (Williamson & Ting, 2001).

Australian cadastral systems have two main components: textual and spatial components (Dalrymple et al., 2003).

Textual component: the land register identifies real property parcels, which includes all land parcels concentrating on those held privately in freehold ownership and identifies owners' rights, restrictions, and responsibilities, ownership, easements and mortgages.

Spatial component: cadastral maps show tradeable land parcels graphically corresponding to the registered title with plan numbers and unique identifiers in a fully computerised system. Treatment of public land and roads varies among the jurisdictions. Cadastral maps consist of fixed and general boundaries, about 90 per cent and 10% respectively. Fixed boundaries are those with legally surveyed measurements used to precisely identify most parcel boundaries determined by cadastral surveys such as a subdivision. General boundaries (graphical) are not survey accurate and are based on natural or artificial physical features, such as high water marks, or walls and buildings as found on building or strata subdivisions.

Crown land management has management and administrative responsibility for state-owned lands. Details of Crown lands, including land parcels leased or licensed to the land registry records (Williamson, 2003).

Additional legal, valuation, local government, utilities and planning activities are involved in land administration, and are heavily reliant on the fundamentals of the cadastral system. In particular, collection of local government rates, land tax and stamp duty (payable on transfer, mortgage and lease of land) relies on land parcels and are major revenue raisers for the state and territory economies (Dalrymple et al., 2003).

Land titles and registry offices in each jurisdiction comprise of very large and complex organisations. They store vast amounts of paper records and now computerise almost all dealings (Dalrymple et al., 2003).

5.3 VICTORIAN LAND ADMINISTRATION SYSTEM

5.3.1 State Context

Victoria is located in the south-eastern corner of Australia. It is the geographically smallest mainland state, but the most densely populated and urbanised (Figure 5.1). Victoria is the second most populous Australian state, after NSW, with an estimated population of 5,603,100 as at March 2012 and a total land area of 227,420 Km2 (ABS, 2012).

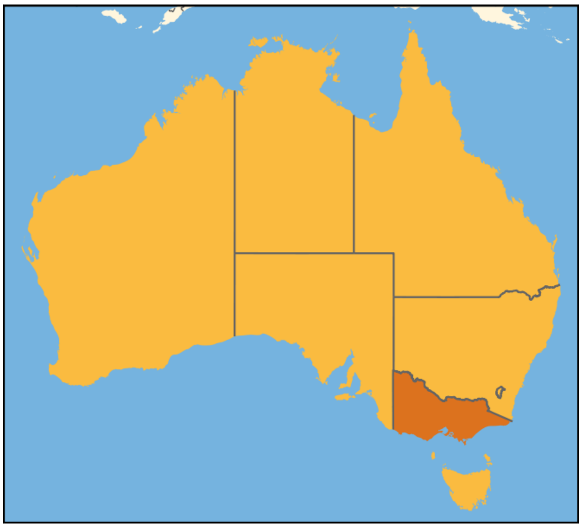


Figure 5.1: Geographic location of the State of Victoria

5.3.2 Victorian Institutional Framework

The Department of Sustainability and Environment (DSE) is the government agency responsible for the management of land, water and natural resources in a sustainable manner in Victoria.

Land Victoria is the DSE's key agency for land administration and land information. Land Victoria collects, maintains and disseminates land related information for the state. Land Victoria registers more than 700,000 dealings per year, with 98 per cent of 2.2 million title searches conducted online. There are 3.2 million current titles securely stored electronically in the Victorian Online Titles System (VOTS) (LandVictoria, 2012b).

The Victorian land administration system consists of two main units: Land Victoria and the Spatial Information Infrastructure (SII). Each group works together with local governments, utility companies, mapping firms, development companies, and a range of public and government departments, banks, solicitors and conveyancers (Figure 5.2).

Land Victoria is responsible for land titles and records, the Victorian Water Registrar, property valuation, surveying, online property information and services, electronic conveyancing, SPEAR (Streamlined Planning through Electronic Applications and Referrals) and geographic place names. Its mission is to provide Victoria's authoritative, comprehensive and easily accessible land administration and land information to underpin effective decision making and appropriate use of land (Kalantari, 2008).

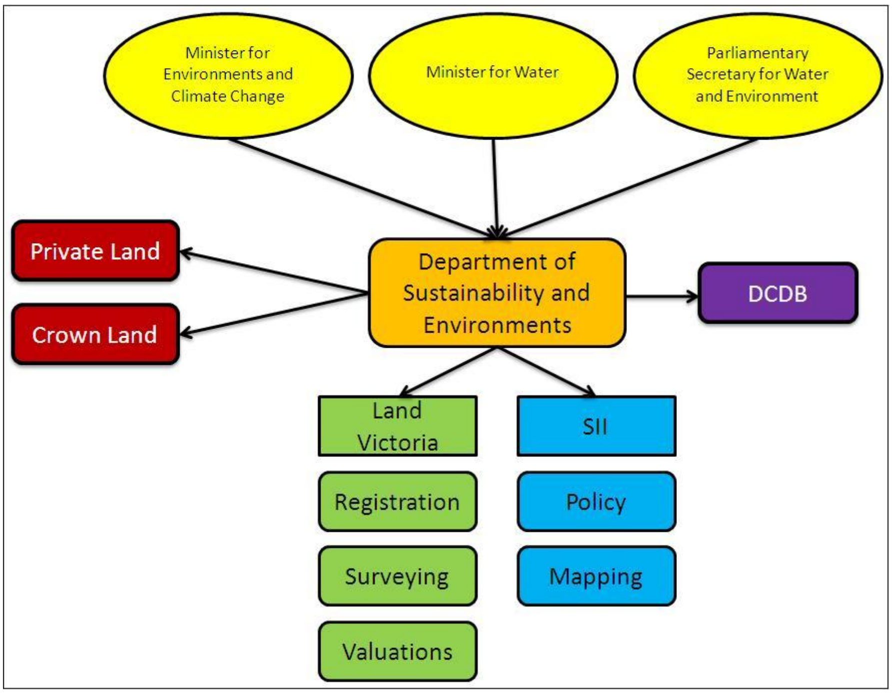


Figure 5.2: Organisational structure of Department of Sustainability and Environments

Spatial Information Infrastructure (SII) is responsible for developing and managing Victoria’s fundamental spatial information and for the Department of Sustainability and Environment’s (DSE’s) corporate spatial information resources.

Land Victoria consists of seven branches, which are responsible for delivering Land Victoria’s services (Figure 5.3). These branches are:

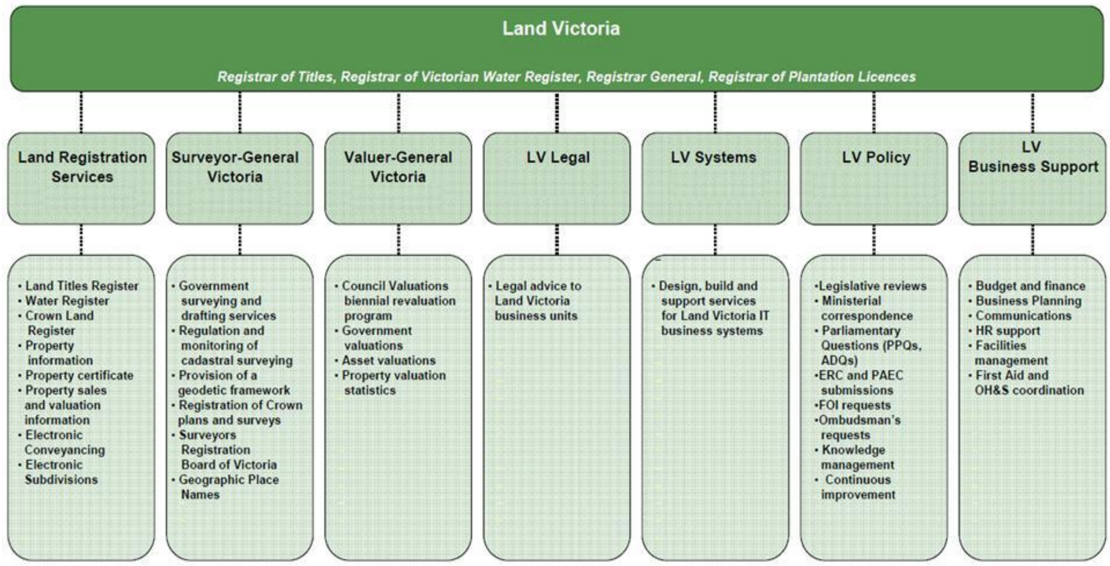


Figure 5.3: Organisational structure of Land Victoria

Land Registration Services

Land Registration Services (LRS) provides authoritative land and related information services through guaranteed title and tenure registration, provision of Crown land status information, access to title, survey and property sales information.

Surveyor-General Victoria (SGV)

Surveyor-General Victoria (SGV) is the Victorian Government's authority on surveying and property boundaries. SGV is responsible for providing and maintaining survey infrastructure, providing survey and drafting services for government agencies, managing the survey components of major government projects, providing technical advice and guidelines for surveying and monitoring the standards of surveys lodged with Land Victoria.

Valuer-General Victoria (VGV)

Valuer-General Victoria (VGV) is the Victorian Government's independent authority on property valuations, which oversees all significant government property valuations and council rating valuations. VGV only does valuations for government agencies. Council valuations are conducted by valuers contracted by councils governed by guidelines established by the Valuer-General of Victoria.

Land Victoria Legal

Land Victoria Legal provides legal advice in relation to acts and regulations that apply to Land Victoria’s businesses.

Systems Group

The Systems Group provides design, build and support services for Land Victoria’s IT business systems.

Policy Group

The Policy Group supports Land Victoria’s businesses in relation to: Quality assurance, Legislative reviews, ERC and PAEC submissions, Auditor-General requests, FOI requests.

Business Support Group

The Business Support Group supports Land Victoria’s businesses and projects with a range of corporate services: Budget and finance, Business planning, Communications, Human resources and workforce management, Facilities management.

5.3.3 3D Property Registration in Victoria

After the 1930s and especially the Second World War, while demands for multiple ownership of land and buildings became more common in Victoria; the legal and cadastral systems have been adjusted and developed to register and meet the needs for housing in apartments and units. Therefore, several Acts and Regulations have been developed in Victoria during a long period of time to register rights, restrictions and responsibilities of multiple ownership of land (Paulsson, 2007).

5.3.3.1 3D Property Registration legislations in Victoria

The development of multiple ownership of land and buildings shows how the legal system is adjusted to meet the needs of the community for housing in apartments and units, and the wishes of developers, owners, mortgagees and planners to meet that demand.

The legal system in Victoria is the common law model, based on Roman law, where a property would reach indefinitely down into the ground and upwards into the sky. In the 1930s, apartments became more common. A company share scheme was developed, similar to condominiums, with title vested in a company where people acquired a share that gave an exclusive right to an apartment. After the Second World War, banks would not accept such shares as security for a loan. Nor was it possible to sell a share without the consent of the other shareholders in the private company (Paulsson, 2007).

Subdivision of buildings was not possible until the middle of the 1950s. A company registered under the Companies Act at that time was used to create separate ownership of apartments (SurveyorsBoard, 1994).

5.3.3.2 Local Government Act 1958 and Transfer of Land Act 1958

The most common type of subdivision is the one that results in one piece of land becoming a number of separate blocks of land (lots). This very basic subdivision of land used to be carried out under provisions of now repealed Local Government Act 1958 and then be registered at the Land Registry under provisions of Transfer of Land Act 1958. This type of subdivision was inflexible in that it only allowed for the subdivision of land along defined horizontal boundaries of the ground (Libbis & Leshinsky, 2008).

5.3.3.3 Company Share Scheme

The first form of using home unit or apartment development was the company share scheme, which was not a subdivision of land. A company was the registered proprietor of the land and owner of the building constructed on the land. The shareholding in the company entitled the shareholder to occupancy rights in a specified part of the building. Since this was not subdivision of land, no approvals were required from planning authorities and the Titles Office was not involved. The main disadvantages with this system were the difficulties in obtaining financing (Albert, 1991).

5.3.3.4 Transfer of Land (Stratum Estate) Act 1960 – Stratum Title

Stratum subdivision is a building subdivision where the building is subdivided into lots or units, and a service company owns the common areas around the units. A lot on the stratum subdivision plan is the airspace occupied by the apartment within the building. In the register, the lot is defined three-dimensionally in space. This act provided a legislative framework for separate ownership of flats. It enables title to be issued for each owners and a title for common areas, which was owned by a service company. Service agreements regulated the relationship between the owners and their rights and responsibilities in respect of the common areas and payment regarding the general expenses of the building, such as repairs and maintenance of the common land and also easements' agreement and insurance for the whole building (Libbis & Leshinsky, 2008).

Stratum subdivisions are still today widely spread throughout the state of Victoria, and in 1994, around 7500 stratum schemes still existed, which means that the surveyor must still be able to handle this type (Paulsson, 2007).

5.3.3.5 Strata Title Act 1967 – Strata Title

When the Strata Titles Act was introduced, own-your-own home units had become very popular, and the pressure for redevelopment of valuable land in the inner suburbs of Melbourne had resulted in the construction of multistoried buildings. The original concept of the Strata Titles Act was to subdivide buildings into strata, the various different levels of residential occupancy of the building (Paulsson, 2007).

Since the stratum system was so complex, a simpler system was created by the Strata Titles Act. A strata subdivision was introduced as a subdivision of land into two or more units, with or without common property. Instead of forming an air pocket, the building was constructed first and then the boundaries related to the building. A strata plan was prepared by a surveyor, sealed by council and registered at the Office of Titles.

Separate certificate of titles for the lots for residence and for the parking lots were created respectively, but not for the common property. When the plan was registered, a body corporate was formed, with functions. Similar to the service company in a stratum development, such as the responsibility for maintenance and insurance (Libbis & Leshinsky, 2008).

5.3.3.6 Cluster Title Act 1974 – Cluster Title

The Cluster Titles Act attempted to resolve the problem of staging and the progressive creation of common property, as well as to provide for pre-selling and to overcome constraints, which applied to site requirements and the sharing of facilities. The Act promised future subdivisions that preserved special site features, such as trees or streams, and the provision of special interest developments, such as tennis courts or stables and horse tracks, but these expectations were not fulfilled. The Act was intended to allow more flexibility and a lessening of some requirements, but instead, more conservative policies were suggested by the municipalities, requiring even lower densities and higher standards than before. Even though several amendments were made, the Cluster Titles Act was not widely used. It was regarded as a failure, with only around 2000 cluster plans approved (Paulsson, 2007).

5.3.3.7 Subdivision Act 1988

The subdivision system before the Subdivision Act was regarded as complex, costly and time consuming. The objectives of the Subdivision Act were to introduce a uniform process for subdivision approvals that are: part of the planning system; a uniform style of title for property in Victoria; a system that is sufficiently flexible to allow for changes to be implemented from time to time; a system that has the municipal council as the central body responsible for the co-ordination of planning, building, traffic and drainage control; and a simplified Act that can more readily be understood by interested users such as developers and members of the bodies corporate. It was regarded as the most advanced subdivision measure in Australia (Libbis & Leshinsky, 2008).

5.3.4 Ownership Boundaries and Plan of Subdivision in Victoria

The lots in a subdivision are defined by their boundaries. These lots can consist of land, airspace, buildings or a combination of those. If a boundary is not identified correctly, this may lead to problems in property transactions as well as other negative consequences (Libbis & Leshinsky, 2008).

According to the 2000 Subdivision (Procedures) Regulations, a plan of subdivision must contain a diagram showing these types of lots ("Subdivision (Procedures) Regulations," 2000).

Before the introduction of the new Subdivision (Body Corporate) Regulations, the boundary between a lot unit and the common property was usually defined as the median, being an invisible line in the wall or window of the unit. This definition led to many misunderstandings and misinterpretation for both occupants and bodies corporate. However, now there must be a notation on the plan that unambiguously defines the location of all boundaries defined by buildings, such as inside face, outside face, median, etc. There is no set method of describing the location of boundaries. The location is dependent on circumstances and the preferences of the surveyor and client. There are, however, some typical notations that are commonly used, for instance for the location of boundaries defined by buildings, where the median for boundaries is marked 'M', the exterior face for boundaries marked 'E' and interior face for all other boundaries (Libbis & Leshinsky, 2008).

Boundaries for a property can be defined by either the national coordinate systems or follow the existing building or road, etc. A national coordinate system was created in 1971. Before this, there were local systems within the different states (SurveyorsBoard, 1994).

The plan of subdivision contains drawings that show the layout of the lots (land, building, air space) and provide all necessary information about the development such as easements and restrictions (covenants) (LandVictoria, 2012a). In a plan of subdivision, cross-sections must be shown on the plan when any parts of the lots, common property, roads or reserves are located above or below other parts

("Subdivision (Procedures) Regulations," 2000). These cross-sections show the upper and lower limits of parcels, on which storey or level the parcels are situated, and stairs, balconies or other features where appropriate. The selection of what type of side view (or elevation) is shown is dependent on both circumstances and personal preferences. There must be sections, elevations or diagrams to fully define overlaps in three dimensions (Paulsson, 2007). It can be concluded that 3D property information is reflected in plans of subdivision in the Land Registry, but they are not represented in cadastral maps and the Digital Cadastral Database (DCDB). Although for tunnels and bridges, Land Victoria provides a limited presentation of 3D data in the DCDB. A classic example of this presentation is the CityLink infrastructure in Melbourne (Aien et al., 2011b).

5.4 CASE STUDY: UNDERGROUND CAR PARK

The digital cadastral map in Victoria is based on land parcels. Properties above or below ground level are not recorded in the cadastral map. However, tunnels and other underground structures might be recorded in the cadastral map. As can be seen in Figure 5.4, the southern part of the University of Melbourne city campus (University Square) is surrounded by buildings and also has an underground car park. The digital cadastral map (Figure 5 .4) represents two-dimensional information. This is part of a case study is to identify the issues around 3D property registration and representation.

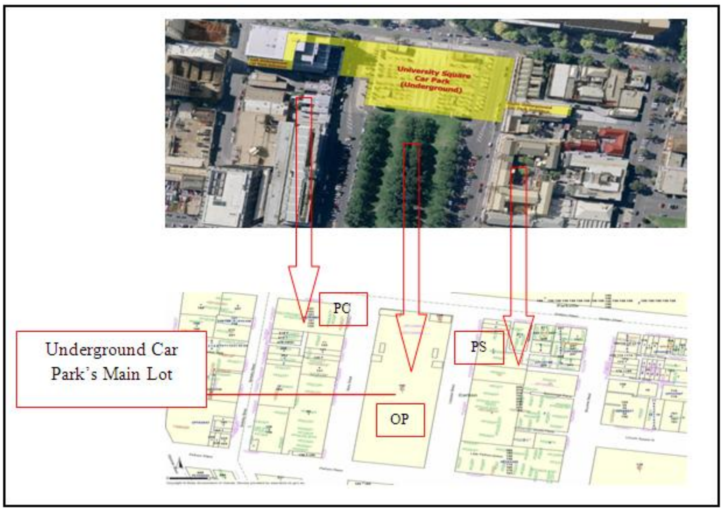


Figure 5.4: Location of underground car park in University Square (Google, 2010) and its corresponding cadastral map (LandVictoria, 2010)

Figures 5.5, 5.6, and 5.7 show plans of survey of the underground car park, which is on Crown land (OP), the location of cross-sections (Figure 5.6), and diagrams of cross-sections (Figure 5.7). The Australian Height Datum (AHD) is used to measure vertical dimensions. With regards to Figure 5.7, elevations of ceilings and the roof are known, where cross-sections are located. Although 3D information is reflected in the plans of subdivision, it is limited to some parts of that and restrictions and conditions are described in the text format and are not fully spatially represented. The problem will be exacerbated if the 3D property has a complex shape where the cross-sections cannot clearly represent the complex building shape.

The lots in a subdivision are defined by their boundaries. These lots can consist of land, airspace, buildings or a combination of these. A plan of subdivision must contain a diagram showing these types of lots. The boundary between a lot unit and the common property is usually defined as the inner surface of the unit, which means that the owner is responsible only for the inner cubic space and interior surfaces of the unit, and the Owners Corporation has clear responsibility for everything beyond this. Other options for the boundary are the median or external face of walls. The developer, Owners Corporation manager and surveyors make decision to determine where the boundary should be located.

However, there must be a notation on the plan which unambiguously defines the location of all boundaries defined by the buildings, such as inside face, outside face, median, etc. There is no set method of describing the location of boundaries. The location is dependent on circumstances and the preferences of the surveyor and client.

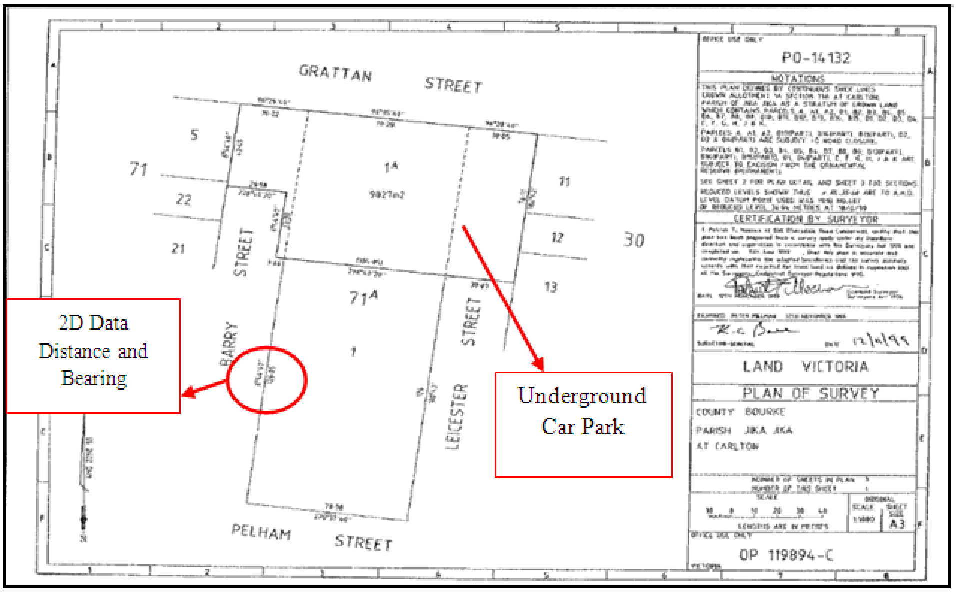


Figure 5.5: Plan of Survey with 2D data – Sheet 1

There are, however, some typical notations that are commonly used, for instance for the location of boundaries defined by buildings, where the median for boundaries is marked 'M', the exterior face for boundaries marked 'E' and interior face for all other boundaries (Figure 5.6).

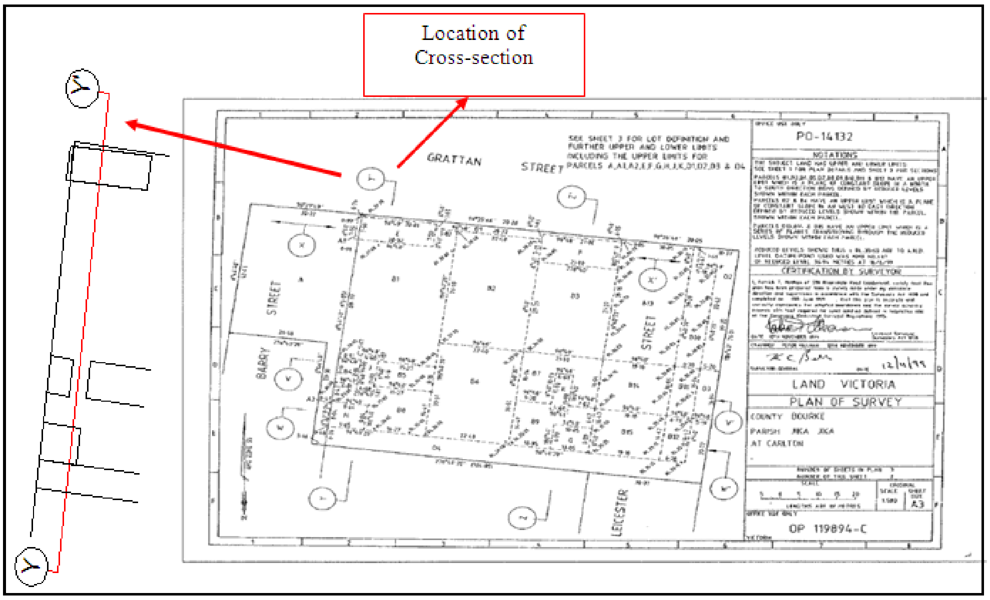


Figure 5.6: Plan of Survey with cross-sections and detailed 2D information – Sheet 2

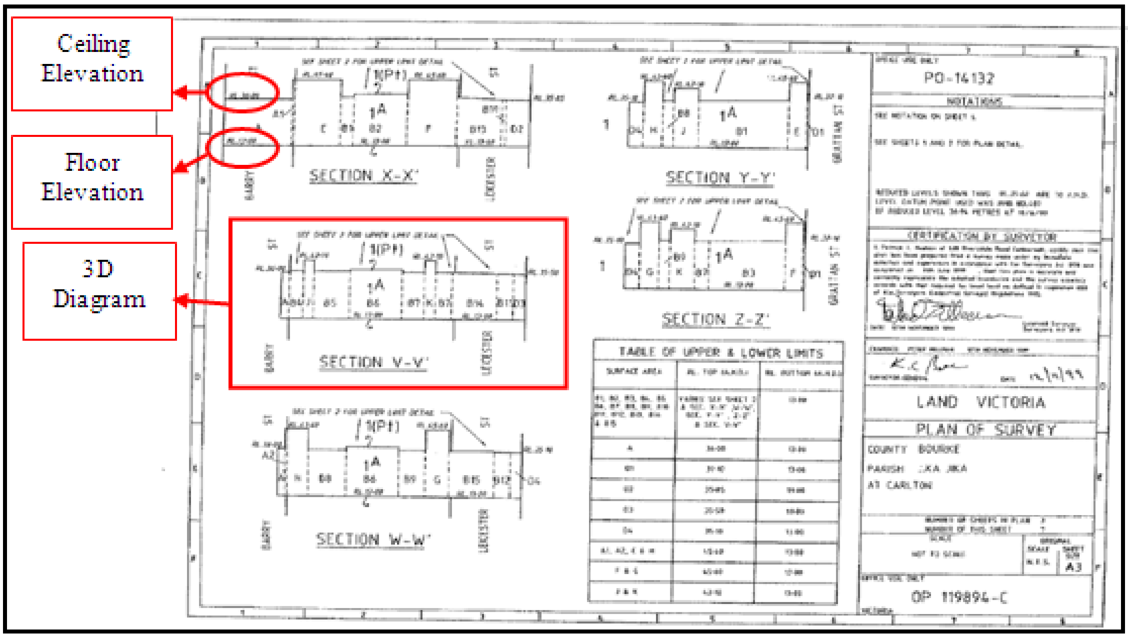


Figure 5.7: Cross-sections on plan of survey – Sheet 3

The west entrance of underground car park passes under the Allan Gilbert building that belongs to the University (shown at top left in figure 5.5), and has a plan of consolidation (PC). Since it is a plan of consolidations, it contains only 2D survey information. Easements and restrictions are not represented in the plan and they are written as text in the notation section of the plan. There is no below ground information or underground entrance details on the plan.

The east entrance of the underground car park passes under another building, which has a plan of subdivision (PS). This plan has four sheets and only represents the 3D information of the building located on the east underground entrance. In the first sheet, easements, restrictions and textual information have been written as text in the notation section of the plan. In the plan of subdivision, 2D survey information is presented for the lower ground level. Cross-sections are also shown on this sheet. The location of an easement has been depicted in Sheet 3 for the basement level. Cross-section diagrams have been drawn on Sheet 4. There is no vertical information for the east entrance of the underground car park and easements and restrictions have not been spatially presented.

As it is clear, current practice of 3D representation requires further improvement to adequately and effectively represent 3D properties. In the following section, complexities of the current method have been assessed to emphasise the need for 3D cadastre.

5.4.1 Assessment of current practice of 3D representation in Victoria

As a result of analysing the current practice of 3D representation in Victoria in the previous section, there are many complexities that are identified in the different plans in terms of 3D and vertical information such as:

- Vertical information only exists in the cross-sections diagrams.
- The location of cross-sections depends on the surveyor's decision and does not conform to a standard.
- The height of ceiling and floor levels are determined in the cross-sections diagrams.
- Lack of continuity between subdivision plans of adjacent lots (west and east car park entrances are not included in the car park subdivision plan and the information is only available from other plans that do not always match).
- The plans are paper-based and cannot adequately represent the 3D structure.
- It is difficult to determine and measure dimensions, area and volume from these plans.
- Many pages are required to depict a simple 3D property.
- Interpretation of these plans is complex and time consuming and requires expertise.
- The plans do not support additional non-spatial information such as textures and colours.
- 3D analysis is not possible on paper plans.
- Some rights, restrictions and responsibilities cannot be spatially represented in the plans.

Overall, 3D plans of subdivision require improvements to represent the actual 3D situation. Although this 3D registration method is effectively being used to register and secure 3D properties in Victoria, the 3D cadastre can improve, represent and manage

3D properties, in addition to 3D visualisation possibilities. 3D analysis also would operate on 3D data to perform different applications.

5.5 CHAPTER SUMMARY

In this chapter, the country profile and discussion of Australia's and Victoria's cadastral systems were explained in order to understand and recognise the current practice of 3D property registration in State of Victoria.

Victoria has the potential to accommodate a 3D cadastre. Victoria's property legislation allows registering of 3D properties and related institutions already have an established close relationship to allow for the development of 3D cadastre; and available 3D technologies provide opportunities to implement 3D cadastre in Victoria.

Progress and development of 3D property legislation meet the demands for 3D registration in Victoria and they forced the representation of the third dimension by using cross-sections on the paper-based plans of subdivision. There is a unanimous opinion and movement toward the development of the 3D cadastre by the public and private sectors. However, there remain some obstacles in developing and implementing the 3D cadastre from a technical point of view.

According to the assessment of the case study (the underground car park), provided information insufficient to produce 3D objects. Vertical information does not exist in all subdivision plans. Non-spatial information such as colour and texture of walls cannot be identified by these plans. Consequently, there is not a sufficient technical potential to develop and implement 3D cadastre in Victoria.

The next chapter describes the first step of 3D cadastral data modelling development cycle in this thesis.

CHAPTER 6 – BUSINESS ANALYSIS AND CONCEPTUAL DATA MODELLING OF THE 3DCDM

6 BUSINESS ANALYSIS AND CONCEPTUAL DATA MODELLING OF THE 3DCDM: DESIGN PHASE OF THE 3DCDM MODEL

6.1 INTRODUCTION

Cadastral data modelling is an active research topic in the land administration discipline as evidenced in the existing various cadastral data models (reviewed in Chapter 3). Various cadastral data models have been developed; however, in the context of 3D cadastres (see Chapter 2), there is not an adequate 3D cadastral data model (see Chapter 3).

A new 3D cadastral data model that is called 3DCDM model is proposed in the following chapters. The methodology to develop the 3DCDM model was based on the data-modelling development cycle in this research (see Chapter 2). The data-modelling development cycle for 3D cadastre consisted of five steps where the first two steps are described in this chapter: gathering requirements of 3D cadastre (business analysis) and developing a conceptual data model for 3DCDM. Developing a logical data model for 3DCDM, step 3, is represented in the next chapter. Step 4, developing a physical data model for 3DCDM, is explained in the Chapter 8. Step 5, designing a 3D Cadastral database, is out of the scope of this research. The results of the first and second step of the data modelling development cycle (gathering requirements of 3D cadastre) are presented as a design phase of the 3DCDM model. This phase conceptualises the structure of the data model and specifies the required data elements and attributes of the 3DCDM model.

6.2 BUSINESS ANALYSIS

Business analysis is an important step defining requirements in the data modelling and database development cycle. The first step is to assess the needs of the users. This step is conducted by interviews and discussions with both the developers (producers) and end users. The basic objectives of business analysis involve: gathering and defining basic objects and data elements; describing the information about the data elements and the relationships among them; and comprehensively documenting all of the requirements (Simsion & Witt, 2005).

6.2.1 Requirements of 3D Cadastre

The research strategy for determining the requirements for the 3D cadastre is to assess the needs of user communities. This information is summarised below. It is based on: the survey conducted by the members of the Intergovernmental Committee on Surveying and Mapping (ICSM) of Australia/New Zealand (ICSM, 2007); from the observations in the '2nd International Workshop on 3D Cadastres', Delft, The Netherlands, Nonember 2011; discussions in the collaborative research workshops on 'Land and Property Management in 3D', the University of Melbourne, Australia, November 2012 and February 2013; interviews and meetings with the research industry partners such as Land Victoria, Vekta, Alexander Symonds; and findings of published works and literature reviews about 3D cadastres and cadastral data-modelling subjects. The results are grouped together to summarise the requirements.

6.2.1.1 Digital 3D data

Most of the jurisdictions currently accommodate 3D properties in cadastral registration, using 2D survey plans, diagrams, and textual references to the third dimension, but 3D land developments are increasingly complex and difficult to interpret.

Digital 3D data is required to simplify the complexity.

Digital 3D cadastre can be used for indexing (searching) and titling systems. The 3D titling system needs more accurate information.

6.2.1.2 Function of 3D cadastre

A 3D cadastre should be able to unambiguously define real property interests in land and air space (it needs to support 3D legal objects).

A 3D cadastre can assist management of multipurpose land, and in time will become an essential base layer for all land administration functions such as land tenure, land value, land use, and land planning (it needs to support 3D physical objects).

6.2.1.3 3D data acquisition

Surveying systems and control networks allow 3D definition of property objects.

Coordinated ground surveys are identified as the main form of obtaining data for 3D cadastres.

The other forms of data collection are also generally recognised as appropriate data collection methods such as uncoordinated ground surveys and measurements, aerial imagery, digitised historical records, depending on the accuracy requirements and circumstances.

Architectural and engineering plans and as-built drawings are also highlighted as main sources of relevant data for 3D cadastres.

6.2.1.4 Rights, restrictions and responsibilities

All 3D cadastres should record at least the same rights as their 2D counterparts.

All interests in land should be the ultimate goal and recorded in 3D cadastre.

There is strong support for more transparency in records of public law restrictions. An extensive list of items now cannot be captured and result in an incomplete and misleading datasets.

Property use should be recorded in a 3D cadastre.

6.2.1.5 Interest holder information

All title and ownership information (land registry information) should be recorded in a 3D cadastral database.

6.2.1.6 Geometry and topology

The 3D cadastral database must contain all information of the survey plans. 3D topological structure is an ultimate goal for 3D cadastre.

6.2.1.7 Accuracy and reliability

Standards for accuracy and reliability should be created collaboratively in response to public and private needs.

Data integrity, common standards and a single, consistent source of information should be considered in a 3D cadastre.

Accuracy and reliability of a 3D cadastre should have a legal mandate.

Data providers for a 3D cadastre (e.g. surveyors, conveyancers) are responsible for the accurate and reliable information.

6.2.1.8 Time

The 3D cadastral database should contain all temporal information of land transactions, legal and physical changes, and re-survey measurements and observations.

Eight main requirements of 3D cadastres were identified by users through business analysis. Needs for digital 3D data, multi-purpose 3D cadastre (which requires both legal and physical objects), different methods of 3D data acquisition (using coordinated cadastral marks, architectural plans), representing all possible interests including land use, maintaining interest holder personal information and the detailed information, which is currently kept in volume folios or other legal documents, supporting various 3D primitives to maintain geometrical/topological requirements, providing accurate and reliable data for 3D titling system, and maintain temporal information were identified as the main requirements of the users of the 3D cadastres.

In addition to recognition of the user’s requirements of the 3D cadastre, identification of the main data elements of 3D cadastres reveals the potential objects of the 3D cadastral data model and assists reengineering data models to respond to the users' requirements (Simsion & Witt, 2005).

6.2.2 Main data elements of 3D Cadastres

It is important to understand which elements of the 3D cadastre will be considered in 3D cadastral data modelling. These elements are extracted from the previous section. The spatial data elements of 3d cadastres are depicted in Figure 6.7 and described below.

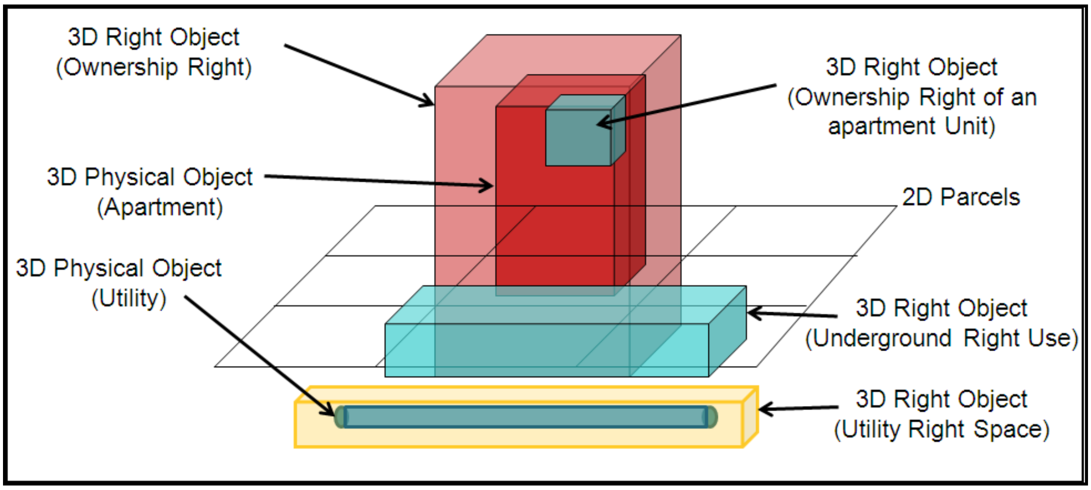


Figure 6.1: Spatial data elements of 3D cadastres

3D physical object

It can be a building, apartment unit, tunnel, pipeline, and terrain surface that belongs to a person, a group of persons or an organisation. The 3D physical objects can be represented by one or a combination of 3D primitives.

3D right object (3D RRRs)

It is the space that the owner of the 3D physical object is entitled to use. It can be, for instance, an ownership right of an apartment unit, an easement in a 3D space such as a party wall, utility right space, or ownership right of the whole apartment complex. A 3D right-object is represented by a 3D parcel. It should be noted that a 3D right object is not always the same as its corresponding 3D right object.

3D parcel

It is a volume of space on, above, or below the ground that defines and represents a particular right, restriction, or responsibility. 3D RRRs are explicitly represented by 3D parcels, but with different rights attached.

Other essential elements of the 3D cadastre are depicted in Figure 6.8. This Figure depicts how different parts are connected together to provide required information to register a 3D property. These required elements are described below.

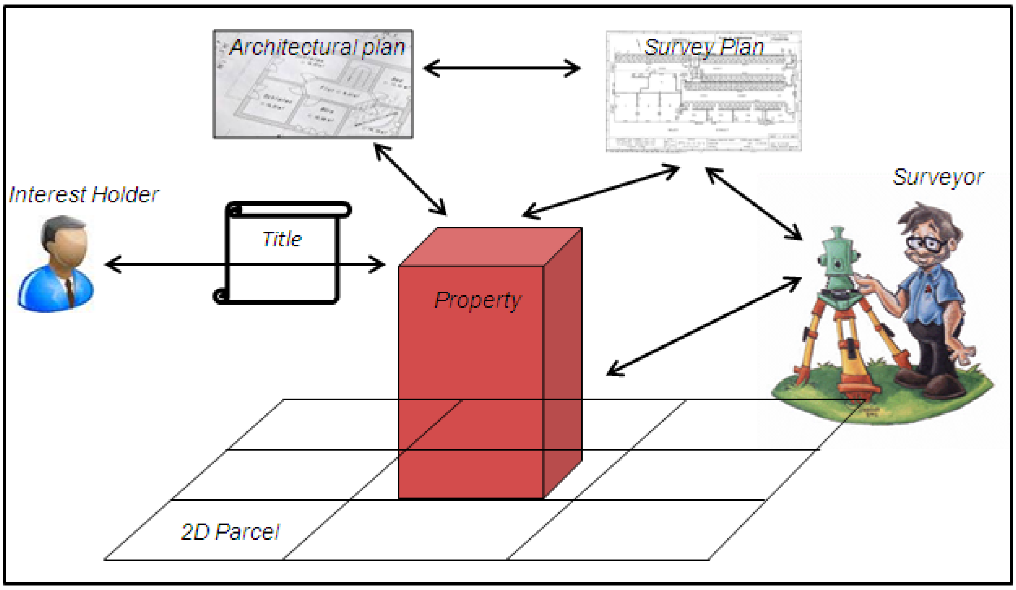


Figure 6.2: various elements of the 3D cadastre

Interest holder

An interest holder can be a person, group, or an organisation who has certain rights (RRRs) over a particular 3D spatial space.

Title

Title or other type of legal documents such as deed, volume folios, mortgages, and agreements provide legal and/or administrative facts about the rights, restrictions, and responsibilities of interest holder with regards to the property.

Surveying

Surveying information describes technical and administrative information of surveying, surveying permanent marks, surveyor, and survey plan.

Survey plan

Survey plans including subdivision plans contain drawings that show the layout of the lots (land, building, air space) and provide all necessary information about the development such as easements and restrictions.

Architectural plan

Survey plans are not detailed enough to guide reconstruction of both legal and physical objects of buildings. Architectural plans are used to generate subdivision plans (legal objects).

These data elements broadly represent what users require to consider in the 3D cadastre. They assist in initial structure and specifications of the data model. The data model, then, is normalised to meet the requirements and to accommodate the user requirements of 3D cadastres, specifications of 3D cadastral data models are described in the next section.

6.2.3 Specifications of a 3D cadastral data model

First of all, land administration systems must deliver accessible, exchangeable, complete, and valid information about people to land (2D and 3D) relationships (ownership models) and manage the huge amount of information in cadastral databases (Lemmen, 2012). Cadastral data models can provide appropriate elements (classes, attributes, relationships) about these aspects. (Henssen, 1995; FGDC, 1996; Kaufmann & Steudler, 1998; Meyer, 2004; Steudler, 2005; Lee & Koh, 2007; FGDC, 2008; ICSM, 2009; ePlan, 2010; ISO19152, 2012).

However, most of the current cadastral data models have been developed based on the definition of a 2D land parcel, neglecting the third dimension. Although a few of them support a 3D object as a component of the data model such as LADM (ISO19152, 2012), they do not use appropriate 3D primitives such as solid geometry to model 3D objects. Solid geometry facilitates 3D representation, volumetric calculation, and 3D spatial analysis.

Secondly, in the context of land and property management, the prerequisite is overlaying 3D physical objects, such as building models, with their corresponding 3D legal objects such as volumetric ownership models (Aien et al., 2011a; Erba, 2012).

For this purpose, 3D cadastres should be equipped with integrated cadastral data models that can maintain both 3D legal and physical objects. In this paper, this data model is called 3D cadastral data model and is not based on the definition of 2D land parcels. Use of this data model enables 3D cadastres to serve multiple 3D applications such as land and property management, virtual legal 3D city, housing transactions and land market analysis, land and property taxation, public communication (tools for real estate agencies), city space management (3D land use management), and 3D site location.

3D physical objects can be achieved by using 3D city models such as CAD files, CityGML (Gröger et al., 2012), or BIM (Isikdag & Zlatanova, 2009); however, these do not support legal or cadastral information. By contrast, cadastral data models such as ePlan and LADM, maintain legal information, but they do not support 3D physical objects. Integration of 3D legal and physical objects in these data models would facilitate implementation of the above-mentioned applications.

Finally, integration of legal and physical models and their interoperability requires semantically enriched information in 3D cadastral data models. Semantic aspects of the data mode allows for ad-hoc combination of distributed sources. Less ambiguity will remain for integration of models if more information is provided by the semantic layer. Simply joining 3D legal and physical models would inevitably lead to geometrical inconsistencies. Semantic information can help to reduce the ambiguities for geometric integration, if it is coherently structured with respect to geometry (Stadler & Kolbe, 2007).

Accordingly, since cadastral purposes (fiscal, legal, or multi-purpose cadastre) can be different in each jurisdiction, different cadastral data models are developed. However, to a large extent they:

- have been developed based on the definition of land-parcel
- do not integrate physical counterparts into cadastral data models
- are not semantically enriched.

The business analysis step provides the requirements to develop a new 3D cadastral data model. Before introducing the data model, principles of 3D cadastral data modelling are proposed in the next section. The aim is to advance the proposition that these principles should be considered in 3D cadastral data modelling by cadastral data modellers to develop an adequate 3D cadastral data model for implementation of a successful multi-purpose 3D cadastre.

6.2.4 Principles of the 3D cadastral data modelling

Based on the specifications of 3D cadastral data models and problems of current cadastral data models, three underlying principles have been proposed in this section. These principles are:

- Principle 1: The 2D land parcel is no longer the most effective building block of cadastres in the dense urban populated areas. It is superseded by the 3D parcel.
- Principle 2: The 3D cadastral data model should not only accommodate 3D RRRs (legal objects); the data model should also represent the physical counterparts of legal objects.
- Principle 3: The 3D cadastral data model should support semantics to facilitate interoperability between legal and physical objects.

These principles are used to be a foundation to design and develop the 3D cadastral data model (3DCDM) in this research.

6.2.4.1 Principle 1: A need to change the cadastral basic building block

The first principle is:

> The 2D land parcel is no longer the most effective building block of cadastres in the dense urban populated areas. It is superseded by the 3D parcel.

This principle reverses the current practice of extending the 2D cadastral model to include the 3D model. Most current initiatives are arguably utilising 2D cadastral concepts for the development of 3D cadastres.

Land parcels play a key role in current cadastral and land administration systems. Cadastral maps represent the spatial extent of land parcels. Cadastral information about owners and their titles is attached to the corresponding land parcels. Land administration processes including recording and dissemination information about ownership, value and use of the land and its associated resources are based on land parcels. Therefore, cadastral data models have been developed based on the definition of a 2D land-parcel (Kalantari et al., 2008).

As discussed in the research background chapter, this approach works satisfactorily for areas where no layered land rights exist. In this case, the owner of a parcel is entitled to use the land in the parcel from the centre of the earth to the heavens according to law and building and urban planning regulations. However, for 3D developments above and below ground, such as apartments, multi-story buildings, tunnels, and utilities, a 2D land parcel is no longer the most effective building block of cadastres. 2D description of parcel boundaries does not adequately explain the relationships among the varied parcels in buildings, especially constructions that involve below ground space. Representation of the arrangements by a series of ‘floor plans’ or ‘ground maps’ that rise up the floors in a building cannot adequately describe the arrangements of legal titles and the opportunities to use the physical structures. The 2D system serves well in simple buildings, and ground level villa unit developments, but management of modern cityscapes would benefit from a much more descriptive capacity in the land administration and titling systems.

Consequently, the 2D land parcel is no longer the appropriate basic spatial component of cadastral models for managing and modelling 3D information in large multi-parcel buildings and for situations that involve layered parcels. In these developments 2D land parcels should be superseded by 3D parcels descriptions. 3D parcels allow the parcels to be volumetrically defined as discrete entities and within the heights of floors and ceilings, shown in Figure 6.3. It is a volume of space on, above, or below the ground that defines and represents a particular right, restriction, or responsibility. It can be, for instance, an ownership right of an apartment unit, or an easement in a 3D space such as a party wall.

By using 3D parcels as the basis to represent the legal situation of 3D developments, the familiar 2D cadastre will be superseded by 3D cadastre, where the geometric and descriptive information of RRRs is based on all dimensions of each parcel. 3D cadastres employ both 2D and 3D parcels to better enable effective management and registration of 3D property RRRs, and for the full range of developments including villa units, multi uses and multi occupancies in a single parent parcel, and those which traverse existing parcels. Figure 6.1 represents a 3D multi-occupancy residential/commercial building (physical representation). Figure 6.2 shows its 2D representation in current cadastral systems (2D legal representation). Figure 6.3 depicts the possible representation of 3D cadastres that is developed based on 3D parcels.

Figure 6.3: Multi-occupancy residential/commercial buildings (Mingru, 2007).

Figure 6.4: 2D parcel representation (Mingru, 2007).

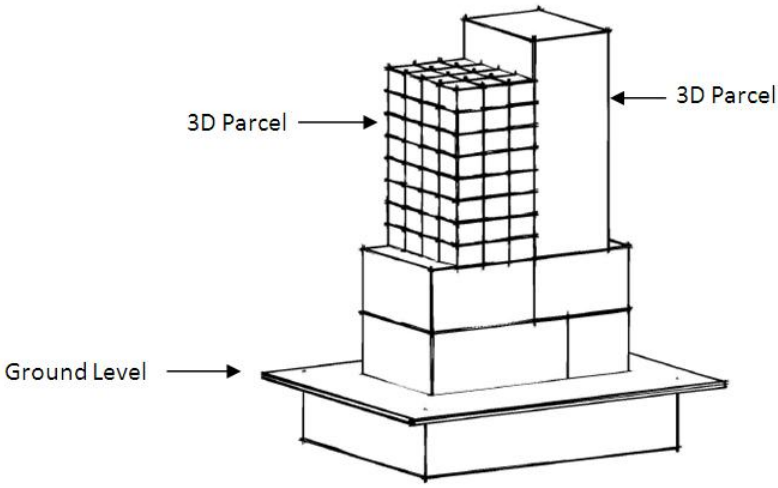


Figure 6.5: 3D parcels which represent the legal situation of the complex building.

6.2.4.2 Principle 2: A need to include 3D physical counterparts of legal objects

The second principle is:

> The 3D cadastral data model should not only accommodate 3D RRRs (legal objects); the data model should also represent the physical counterparts of legal objects.

This principle challenges the original definition of the cadastre where land parcels are kept as an attachment to land titles. This principle requires a higher degree of integration between RRRs and their physical counterparts.

The basic building block of the cadastres is superseded by 3D parcel based on the first principle. Hence, the question:

'Is capacity to visualise legal information (spatial and descriptive information) alone enough for 3D cadastral purposes, which ideally should deliver clear registrations of 3D parcels?'

This is answered in this research by:

'No'. As it can be seen in Figure 6.4, the boundary between adjoining 3D parcels is still ambiguous. The exact position of boundaries between horizontal and vertical neighbours is not clear. Users expect 3D RRRs to be visualised in a 3D cadastre. However, visualisation of 3D RRRs alone would not adequately assist management of 3D RRRs (Aien et al., 2011a).

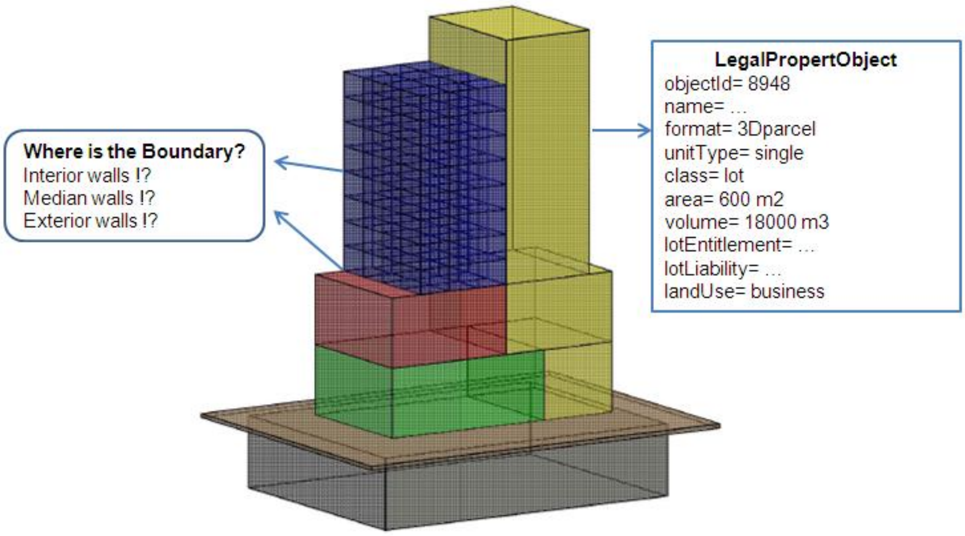


Figure 6.6: 3D legal representation using 3D parcels and related cadastral information

The first idea that usually comes to mind regarding representation of 3D cadastral objects is using basic 3D model primitives such as boxes, prisms, spheres, and cylinders, but these simple geometric objects have proved insufficient to analyse urban space, because they lack sufficient flexibility to represent reality. To match 3D cadastres more closely with reality, researchers and designers have developed the Building Information Model (BIM) and virtual 3D city model (cityGML) that are capable of representing 3D urban objects, and provide techniques to overlay photographs of building facades on building surfaces, and represent all architectural characteristics equivalent to a building using 3D computer-aided design (CAD) software (Erba, 2012).

Moreover, the cadastral datasets are often used to integrate with other datasets, such as transportation and utility network datasets to serve additional purposes such as facilities management, base mapping, value assessment, land-use planning, and environmental impact assessment. Also, the 3D cadastre data model should cater for a broad range of land administration functions including land tenure, land value, land use, and land development with sufficient detail. A legal basis, however, often does not exist to support all of these other purposes. The actual construction of the buildings (physical information) should be visualised in 3D cadastres for different land administration functions and applications.

Current cadastral data model do not integrate corresponding physical models with 3D legal entities (3D parcels). Specifications of the 3D parcel show that structures of building models such as walls are used to define the boundary of 3D parcels (Table 1.1). Thus, cadastral models should support physical models when they are modelling 3D developments such as multi-story buildings.

Table 6.1: Comparison of 2D land parcel and 3D parcel specifications

Building Bock / Specification	**2D Parcel**	**3D Parcel**
Geometry	Surface (Polygon)/ Line segments	3D Solid/ Multi-surfaces
Boundary Definition	Parcel boundary	Defined by structures (wall, ceiling, roof)
Creation, Manipulation	Simple	Complex
Representation	2D Representation (paper or screen)	3D digital format
DBMS	Support	Rarely support
Spatial Analysis	Simple	Complex

3D parcels may utilise the structure of a building to specify the location of boundaries (Figure 6.5). Location of boundaries within a development must be clear to owners, purchasers, builders and developers, licensed surveyors, land registry officers, relevant council officers, notaries, solicitors and owners corporation managers.

From a legal point of view, when 3D parcels contain building boundaries, the location of those boundaries must be defined by stating whether those boundaries lie along the 'Interior face', 'Exterior face' or the 'Median' of the relevant physical structure. This applies especially to boundaries between lots, and between lots and common property.

Interior face, for example in Victoria, Australia, lies along the interior face of any wall, floor (upper surface of elevated floor if any), ceiling (underside of suspended ceiling if any), window, door or balustrade of the relevant part of the building. Any internal coverings, water proof membranes and fixtures attached to walls, floors, and ceilings are included within the relevant parcel ("Subdivision (Registrar's Requirements) Regulations," 2011). Figure 6.5 illustrates where the location of interior boundaries lies between two adjacent units (lots). Selecting the interior face as the parcel boundary generally means the structure of the relevant wall, floor, and ceilings is to be contained in common property.

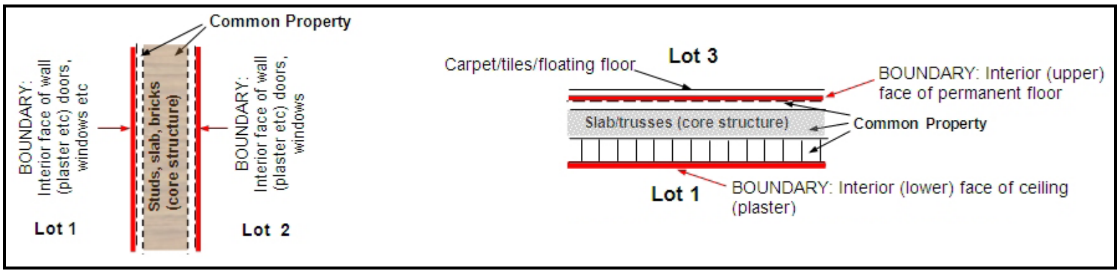


Figure 6.7: Interior face of internal walls (Left) and internal floors/ceiling (Right) (LandVictoria, 2012a)

Currently cross-sections or isometric diagrams are used to represent the location of building boundaries in the plans of subdivision. Cross-sections must be shown on the plan when any parts of the lots, common property, roads or reserves are located above or below other parts ("Subdivision (Procedures) Regulations," 2000). These cross-sections show the upper and lower limits of parcels on which storey or level of the parcels is situated, and stairs, balconies or other features where appropriate. However details of these individual features are not depicted on the plan of subdivision and the type of the boundary in terms of 'interior', 'median', and 'exterior' is written as a notation in the subdivision plans (Figure 6.6, Right).

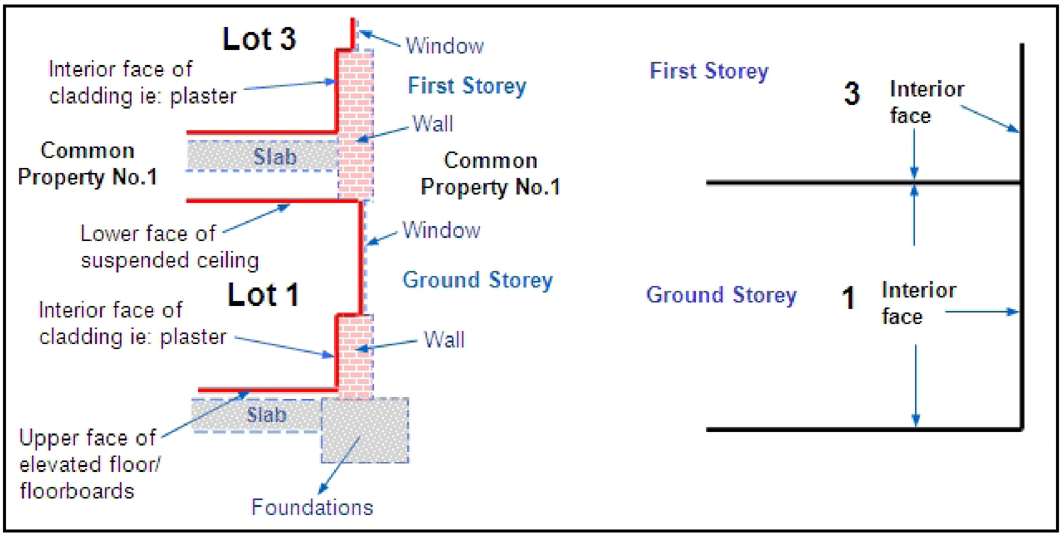


Figure 6.8: Interior face of internal walls and the structure of the relevant wall is to be contained in common property (physical view) (Left) and its representation in the subdivision plans (legal view) without depicting the structure. The common property is not clearly shown in the cross-section view (LandVictoria, 2012a).

Boundaries of 3D parcels (ownership spaces) are defined based on the actual structures of a building to determine the legal volume. In the paper-based plans of subdivision, the boundaries of ownership are only representative. For building subdivisions, from legal perspective, the actual structure of the building defines the ownership spaces. In other words, the legal definition is equal to the physical definition. In the digital world, it is therefore necessary to have physical definition of the buildings in the cadastres. Therefore, visualising 3D parcels only in 3D cadastres does not clearly represent the actual information of ownership rights, restriction, and responsibilities. Using 3D parcels alone without integrating with their physical counterparts such as building structures still will not solve existing ambiguities that affect interpretation of the relationship between the rights and building interests, and will not reduce boundary confusion among owners and owner corporations. Integration of physical and legal objects, by contrast, will clearly represent the legal structure of a building.

Therefore, the 3D cadastre data model should support both legal and physical objects of a 3D property. While representation of legal objects is the main target of cadastral systems, representation of physical objects would serve for different applications. For example, land registrars need parcel scale information, meaning that they need to register and visualise subdivided 3D spatial objects and their associated rights that are represented in survey and subdivision plans. On the contrary, urban planners may need large-scale city-wide datasets, or potentially more detailed information in every unit and storey of a building. This information is represented in the architectural and engineering plans (Figure 6.9).

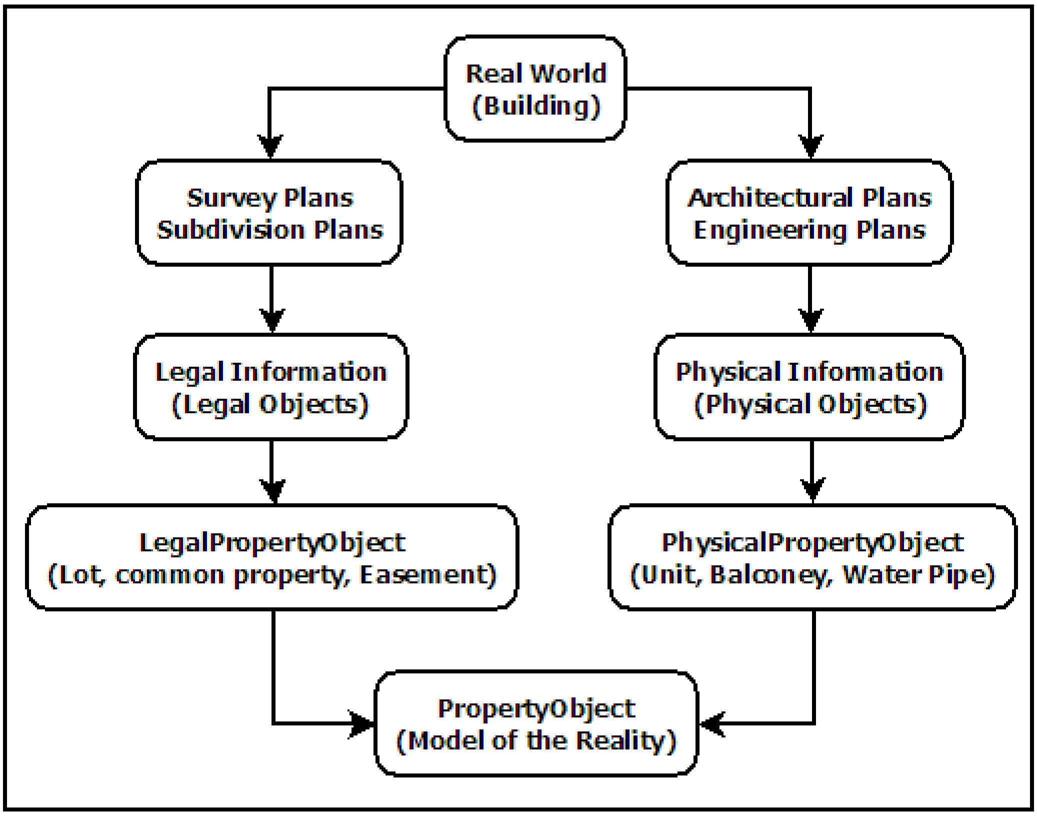


Figure 6.9. Acquisition process of legal and physical information for 3D cadastre

6.2.4.3 Principle 3: A need to support semantics in 3D cadastral data models

The third principle is:

The 3D cadastral data model should support semantics to facilitate interoperability between legal and physical objects.

This principle maximises the efficiency of the 3D cadastral data models and facilities the integration of legal and physical objects.

3D cadastres can be used by different customers within multiple applications, provided a common information model could extend over the different users and applications. A semantically enriched 3D cadastral data model would then enable collaboration in heterogeneous environments.

On the semantic level, legal entities, such as lots, easements, and common properties of existing cadastral data models, are represented by application objects, for example parcels or spatial units, including attributes, relations, and aggregation hierarchies between objects. However, in the current cadastral data models objects that represent legal entities are not semantically enriched.

Integration of 3D legal objects with their physical counterparts is far from easy. Since legal and physical objects are often maintained separately, integration inevitably leads to geometrical inconsistencies. Semantic information can help to reduce the ambiguities for geometric integration, provided it is coherently structured with respect to geometry (Stadler & Kolbe, 2007). Therefore, integration of 3D legal and physical objects and their interoperability requires semantically enriched information in 3D cadastral data models. Semantic aspects of the data model allow for an ad-hoc combination of distributed sources. Ambiguity affecting integration of models will be reduced if more information is provided by the semantic layer.

After proposing the principles of 3D cadastral data modelling and analysing the business requirements of 3D cadastres, it is time to connect all major entities and elements of 3D cadastre as a conceptual data model. The conceptual data model is presented in the next section.

6.3 CONCEPTUAL DATA MODEL OF THE 3DCDM

In this section, the second step of the data-modelling development cycle is proposed. The methodology to develop the conceptual data model of the 3DCDM is to develop the conceptual model from the core cadastral data model step by step. The conceptual model is presented in the Unified Modelling Language (UML) diagrams.

In the first step, the logical model of the core cadastral data model is represented. Then, this data model is modified to support the concept of the Legal Property Object. The logical model of the Legal Property Object model is created and its components are demonstrated. The Legal Property Object model forms the legal hierarchy of the 3DCDM model. The Physical hierarchy of the 3DCDM model that supports the physical counterparts of the legal objects (Legal Property Objects) maintains related objects such as building, tunnel, utility, and terrain model. Both hierarchies are described in the following sections.

6.3.1 Conceptual model of the core cadastral data model

Cadastres are dealing with entities consisting of interests in land that have three main components: Parcel, Right, and Person (Henssen, 1995; Oosterom et al., 2006). The spatial unit of a legal object are surveyed and demarcated by geometrical objects, while their legal descriptions (legal documents and interest holder information) are kept in the land registry (Figure 6.10).

The laws define the outlines of the legal objects. The legal objects normally are described by boundaries that demarcate where a right or a restriction ends and where the next begins and the contents of that right (Kaufmann & Steudler, 1998).

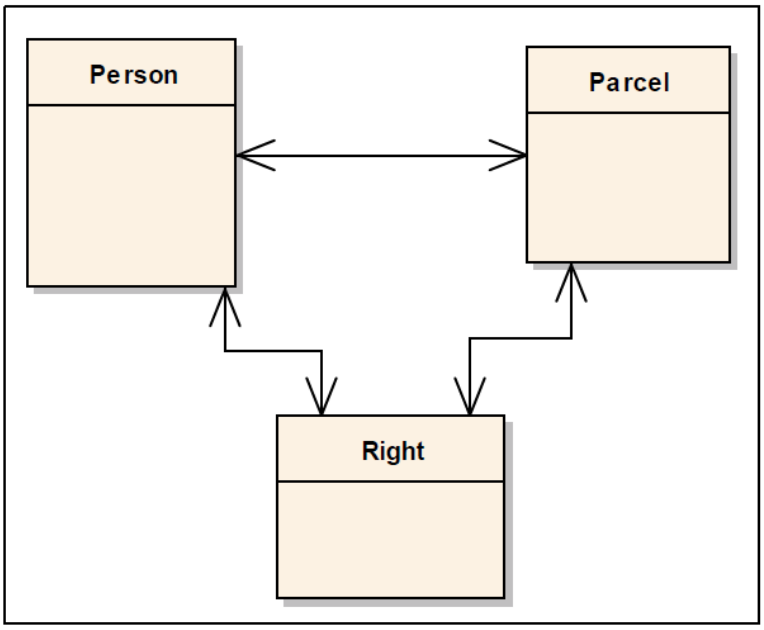


Figure 6.10: Main components of current cadastral data models

The UML diagram in Figure 6.10 represents the core components of most current cadastral systems (Meyer, 2004; Steudler, 2005; FGDC, 2008; ePlan, 2010; ISO19152, 2012). In this model, Parcel and Right are linked together by unique identifiers (the parcel identifier). Parcel identifier is employed for organising land information.

Since cadastres are now under pressure from various land related commodities and stratified interests (as explained in the first principle of 3D cadastral data modelling), spatial unit (parcel) based indexing of interests in land cannot accommodate interests that are not necessarily equivalent to the extent of spatial units or land parcels (Kalantari et al., 2008). Legal Property Object model restructures the concept of the core cadastral data model from a land parcel-based data model to a spatially referenced data model.

6.3.2 Conceptual data model of the Legal Property Object

The Legal Property Object was proposed by Kalantari (2008) to replace the core cadastral data model by a spatially referenced data model based on the Legal Property Object concept that uniquely combines every interest and its spatial extent. The Legal Property Object includes a particular interest with its spatial dimensions.

Although land interests (RRRs) can be maintained by different organisations and have particular characteristics that drive RRRs as a separate class in cadastral data models (Lemmen, 2012), combining RRRs and *SpatialUnit* classes into one class, Legal Property Object class (Figure 6.11), facilitates the incorporation of a wide range of RRRs into the cadastral system. Interoperability and simplicity in data-exchange processes, particularly upgrading and updating cadastral databases using spatial referencing systems, are promoted (Kalantari et al., 2008).

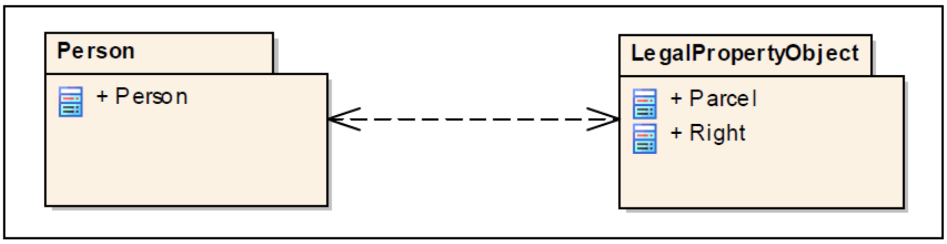


Figure 6.11: New cadastral data model based on the Legal Property Object concept, adopted from (Kalantari, 2008)

Once the advantages of utilising the concept of Legal Property Object have been described and utilisation of this concept in the 3DCDM model can be considered. The following discussion describes how the Legal Property Object model is used in the 3DCDM model.

6.3.3 Utilisation of the Legal Property Object (LPO) model in the 3DCDM

As concluded in Chapter 3, the proposed 3D cadastral data model (3DCDM) utilises the concept of the Legal Property Object model. The reason is this concept re-engineers the core cadastral data model from a land parcel-based data model to a spatially referenced data model. As a consequence, different kinds of interests in land are reflected in various Legal Property Objects layers in a cadastral information system. This trend facilitates the inclusion of all interests comprehensively and accommodates the increasing number of new interests in land. 3DCDM model is developed based on the concept of the Legal Property Object.

The Legal Property Object allows for the representation of spatial aspects of legal objects (2D and 3D). The UML diagram of Legal Property Object model is depicted in Figure 6.12. In this model, the *LegalPropertyObject* represents all land interests (rights, restrictions, and responsibilities). It is created using its associated features such as *LegalDocument*, *InterestHolder*, *Geometry* and *Address*.

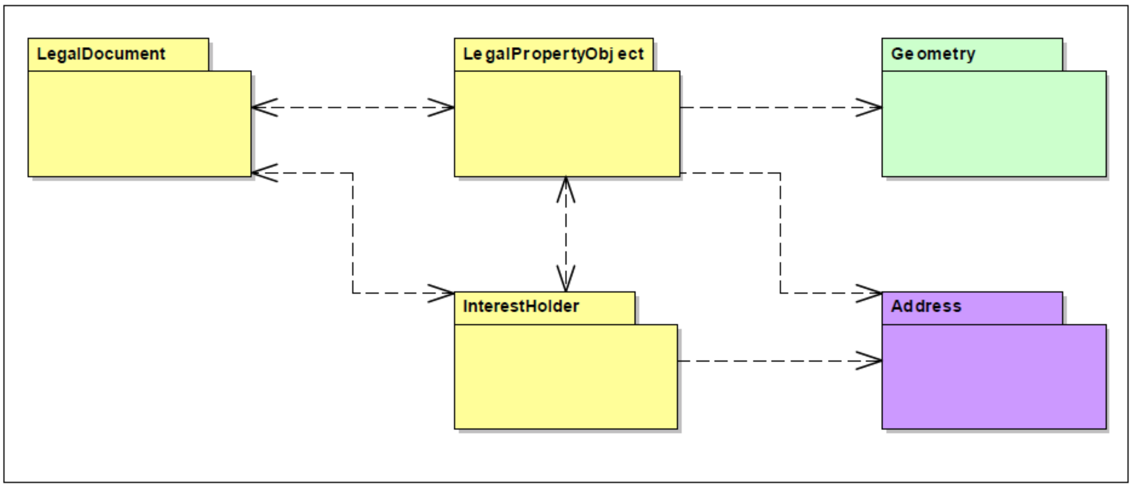


Figure 6.12: LegalPropertyObject's package view, adopted from (Kalantari, 2008)

The *LegalDocument* package contains authoritative and registered documents such as titles, deeds, or agreements. It defines rights or ownership of property attached to the Legal Property Object. The *InterestHolder* package maintains information about the interest holder of the Legal Property Object and the *Address* package maintains the physical address of the Legal Property Object and living address of the interest holder. The *Geometry* package includes zero, one, two, and three-dimensional geometric primitives to represent spatial extent of the Legal Property Object. The Legal Property Object model is the core component of the 3DCDM model.

3DCDM model as a 3D cadastral data model follows the advanced principles of 3D cadastral data modelling. Three advanced principles of 3D cadastral modelling were proposed as a result of the Business analysis step in this chapter. The following sections illustrate how these principles apply to the 3DCDM model.

6.3.4 3DCDM model and the first principle

Based on the first principle, 2D land parcel is no longer the most effective building block of cadastres. It is superseded by 3D parcel. In 3DCDM model, *LegalPropertyObject* class plays the role of a 3D parcel. It contains required legal object information and its spatial properties are represented by 2D or 3D geometrical primitives (Aien et al., 2012).

The geometric representation of a *LegalPropertyObject* class is shown in Figure 6.13. A *LegalPropertyObject* can be represented by 1-dimensional geometric primitives, such as *GM_MultiCurve*; a 2D object, such as a land parcel or with *GM_MultiSurface* (surface with z value); or 3-dimensional geometric primitives, such as solid, when the *LegalPropertyObject* is a 3D object.

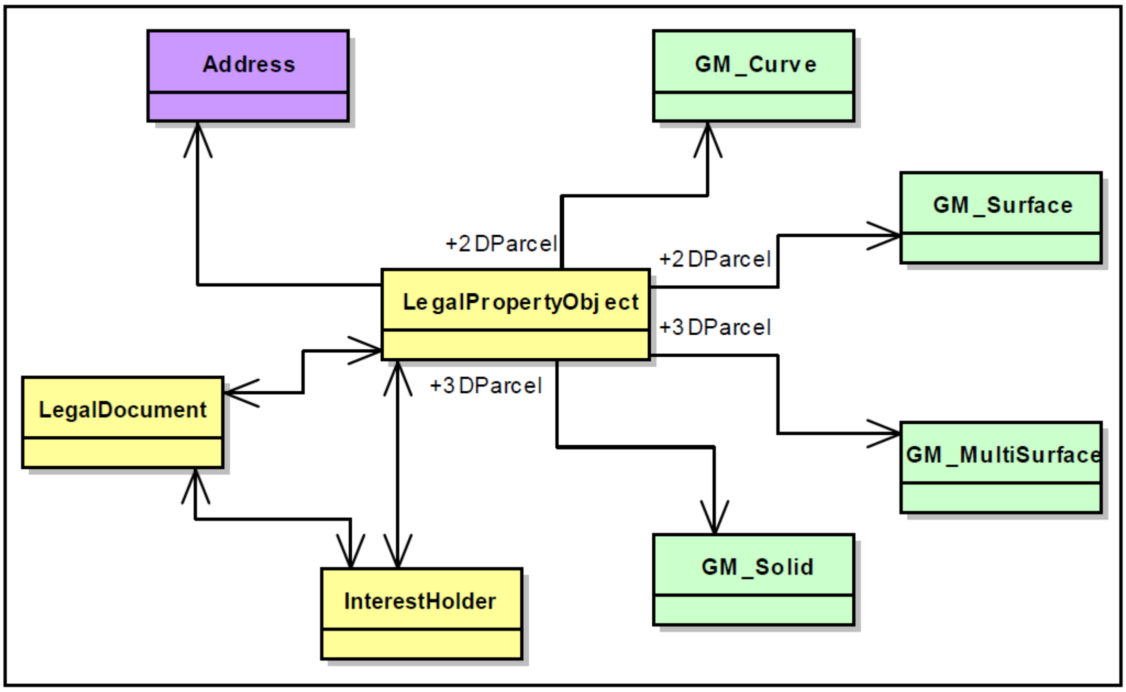


Figure 6.13: Conceptual model of the *LegalPropertyObject*

Few cadastral data models support 3D parcels to model 3D RRRs (see Chapter 3). However, they do not use solid geometry (Solid) to represent 3D parcels. Solid geometry facilitates 3D representation, volumetric calculation, and 3D spatial analysis. 3DCDM model supports solid representation.

Each *LegalPropertyObject* class is associated with an *InterestHolder* class, which maintains interest holder's information and a *legalDocument* class that maintains authoritative and registered information of the legal object. *LegalPropertyObject* class is also associated with the *Address* class.

6.3.5 3DCDM model and the second principle

Based on the second principle, there is a need for integration between legal objects and their physical counterparts. Figure 6.14 illustrates how legal objects are associated with their physical counterparts in 3DCDM model. The *LegalPropertyObject* represents any type of legal object. Each *LegalPropertyObject* has one or more owners (*InterestHolder*). Each *LegalPropertyObject* is associated with zero or more abstract *_PhysicalPropertyObject*, which has four subclass specialisations: *Building*, *Land*, *Tunnel*, *_UtilityNetwork*, and *PhysicalPropertyObject* (any type of Physical Property Object such as a mine, road, or sea). The association between *LegalPropertyObject* and *_PhysicalPropertyObject* is bi-directional, which means that it is possible to navigate from each hierarchy (legal or Physical) to find the corresponding object.

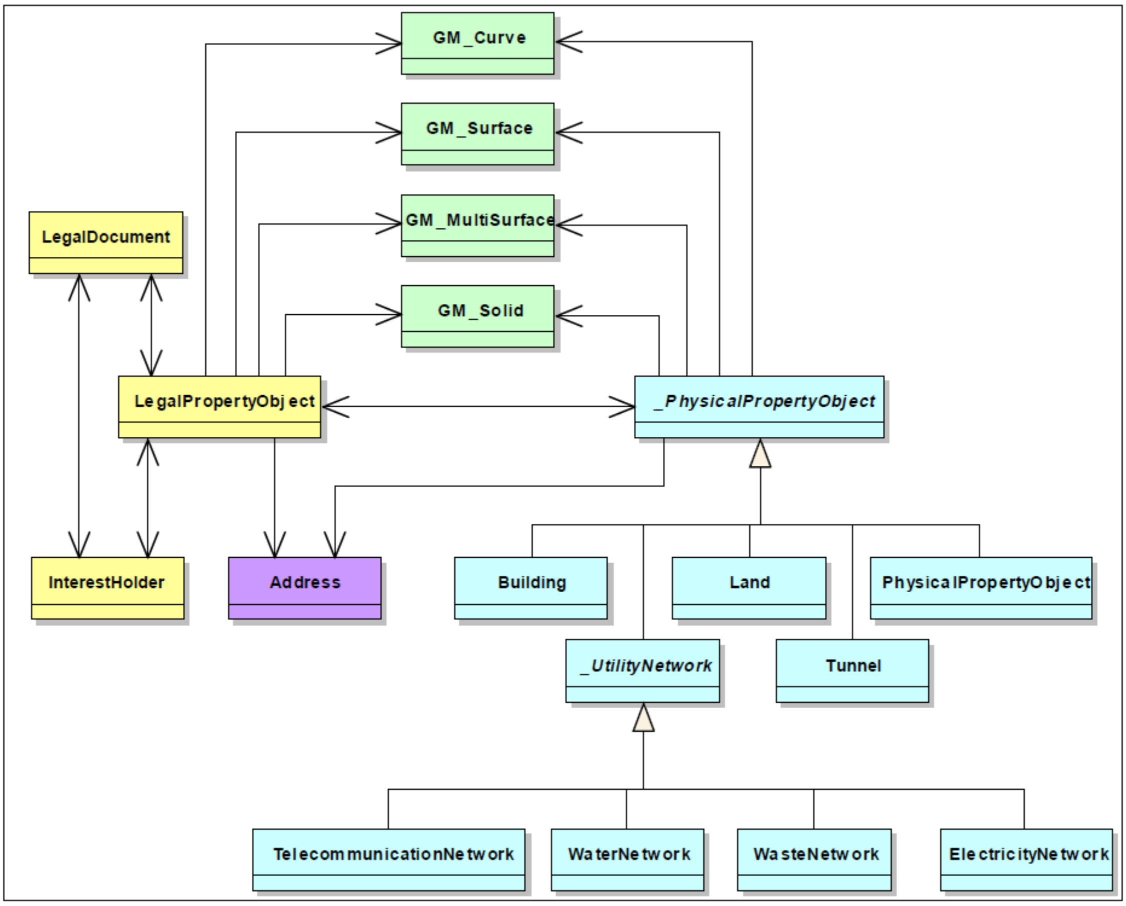


Figure 6.14: Conceptual model of integrating the legal and physical objects in the 3DCDM model

_PhysicalPropertyObject class is a superclass in the physical hierarchy of 3DCDM model, while *LegalPropertyObject* class is the core class in the legal hierarchy. Physical hierarchy is represented in light blue and legal hierarchy is represented in yellow to be easily distinguishable. *Geometry* classes are in green and *Address* in purple.

Physical Property Objects are important for cadastral applications. Having separate *PhysicalPropertyObject* class facilitates a selection of an appropriate *PhysicalPropertyObject* for any particular application. In terms of modelling a building, only *Building* subclass is used. Also *Building* class can be aggregated with *Tunnel* class and *_UtilityNetwork's* subclasses to provide more comprehensive model. Each subclass has its own subclasses and different types of interrelationships between feature classes like aggregations, generalisations, and associations, which will be presented in the next Chapter.

In the 3DCDM model, all physical and legal objects have a unique *objectID* in the entire model. In this method, in the legal hierarchy, a *LegalPropertyObject* is generated and an *objectID* is assigned to that. Also, in the physical hierarchy, a *PhysicalPropertyObject* such as a building, a unit, a wall, or a water network is created and its corresponding legal object is referenced by attributes (*objectID*). If the *PhysicalPropertyObject and its counterpart* have a similar geometry, then the geometry is only created for the *PhysicalPropertyObject* and the geometry of the corresponding *LegalPropertyObject* will be represented by referencing to its physical object.

6.3.5.1 Methods of integrating legal and physical Objects

Legal objects can be integrated with physical objects using relative and absolute methods in the 3DCDM model.

The relative method can be used when a physical model has already been created. A unique identifier (*objectID*) is associated to every piece of a physical object in the model. Then, legal objects are linked to their corresponding physical counterparts using these identifiers. If a piece of a legal object can be referenced to its corresponding physical object, this method is exercised. Otherwise am absolute method is used to create the legal object.

In the *Building* model, for example, each unit is defined by interior and exterior surfaces of wall, roof, and ceiling. Each surface has an object identifier in the 3DCDM model, which is unique to the entire model. Boundary surface of a legal object can refer to this identifier without reconstructing and duplicating the geometry.

The absolute method is used when legal objects are not coincident with physical objects. It is important to realise that legal objects do not necessarily coincide with their corresponding physical objects mostly in cases of airspace and common properties (Lemmen, 2012). However, legal models can be spatially defined using three dimensional absolute survey points as illustrated in the model in Figure 6.14. This method is used in current cadastral systems for creating 2D land parcels.

6.3.5.2 Example of integration of legal and physical objects

Figure 6.15 is a cross-sectional view of a two-storey apartment with four units and one access way. All slabs and exterior walls are common properties and each unit is owned by different people. Figure 6.16 represents a subdivision plan that is registered in a land registry office. As it can be seen, common properties are not explicitly represented in the subdivision plan.

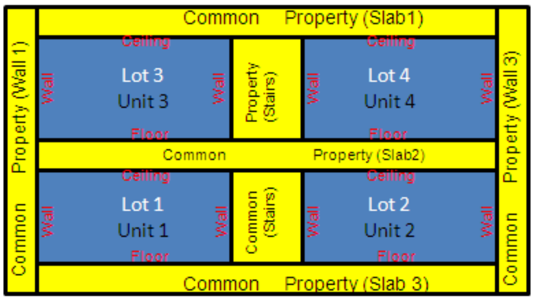


Figure 6.15 A cross-sectional view of a two-storey apartment with four units and one access way area.

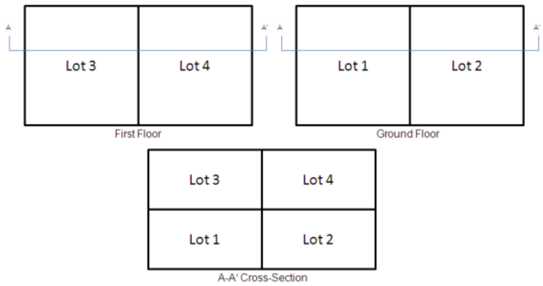


Figure 6.16 A subdivision plan that is extracted from the structure of a building (physical information).

In contrast, an integrated model that incorporates the physical information of the building (building structures) can clearly represent the legal information. This model can be used for other applications. The result of the model is something like Figure 6.17.

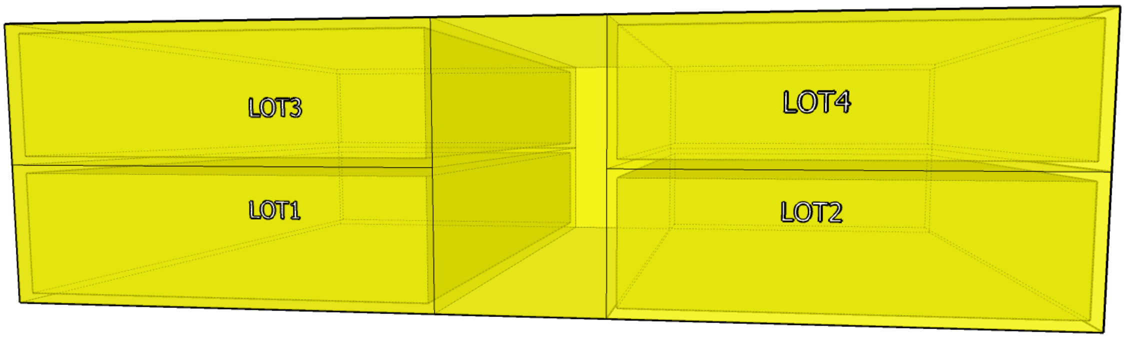


Figure 6.17 Example of a legal and physical integration

6.3.6 3DCDM model and the third principle

Based on the third principle, there is a need to utilise semantics in cadastral models. Therefore, these models can be used for visualisation, thematic queries, and spatial analysis purposes.

3DCDM models legal and physical objects with the semantics associated with the data. There is a coherent modelling of semantics and geometrical properties in 3DCDM model. Furthermore, attributes and associations between features support semantics.

Semantically, legal objects are represented by *LegalPropertyObject*. *LegalPropertyObject*'s attributes identify the type of the legal object and further support semantics. For example, the *LegalPropertyObject* object can be an ownership, common property, easement, covenant, or license. Physical objects also are represented by features such as *Building*, *Land*, *Tunnel*, *_UtilityNetwork* (Figure 6.14).

Spatially, geometrical objects represent the location, boundary and extent of the legal and physical objects, while each geometrical object is instantiated by semantics in 3DCDM model. Figure 6.18 represents how geometrical objects (green objects) are linked to their corresponding semantics.

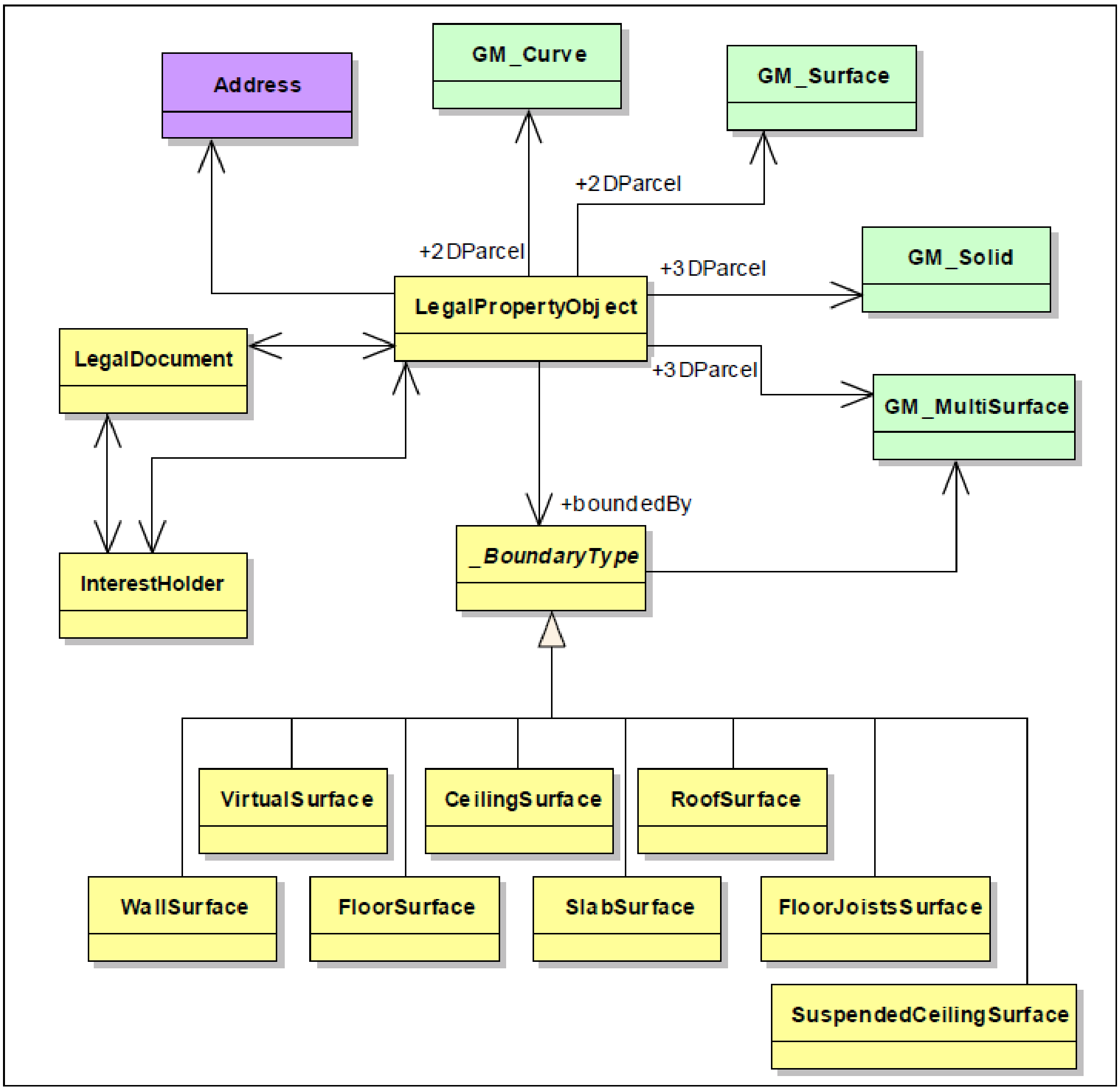


Figure 6.18 Spatially and semantically coherent conceptual model of the *LegalPropertyObject*

In this model, solid geometry (*GM_Solid*) is used to spatially create a 3D *LegalPropertyObject* such as a volumetric ownership space of a unit in a building. In addition, *BoundayType* class specialisations such as *VirtualSurface*, *WallSurface*, *FloorSurface*, and *CeilingSurface* are used to semantically enrich the created *LegalPropertyObject*. This concept applies to the physical objects as well. Therefore, all legal and physical objects in the 3DCDM model are enriched with semantics. The logical model of 3DCDM, which contains all classes, attributes, and associations will be presented in the next chapter.

Using 3D geometrical objects, integration of legal objects with their physical counterparts, and support semantics, 3DCDM model follows the rules of the advanced principles of 3D cadastral data modelling. In addition, 3DCDM model supports surveying information that was identified as main requirements in the business analysis step. Surveying information including observations and cadastral control points, which are important elements in cadastral plans, are considered as a separate module in 3DCDM model. Figure 6.19 represents the conceptual model of 3DCDM, which includes the main features of the 3D cadastre. As previously discussed, 3DCDM model has two hierarchies, legal and physical. Survey and CadastralPoint are included in the legal hierarchy. They cover the required surveying information of the Legal Property Object.

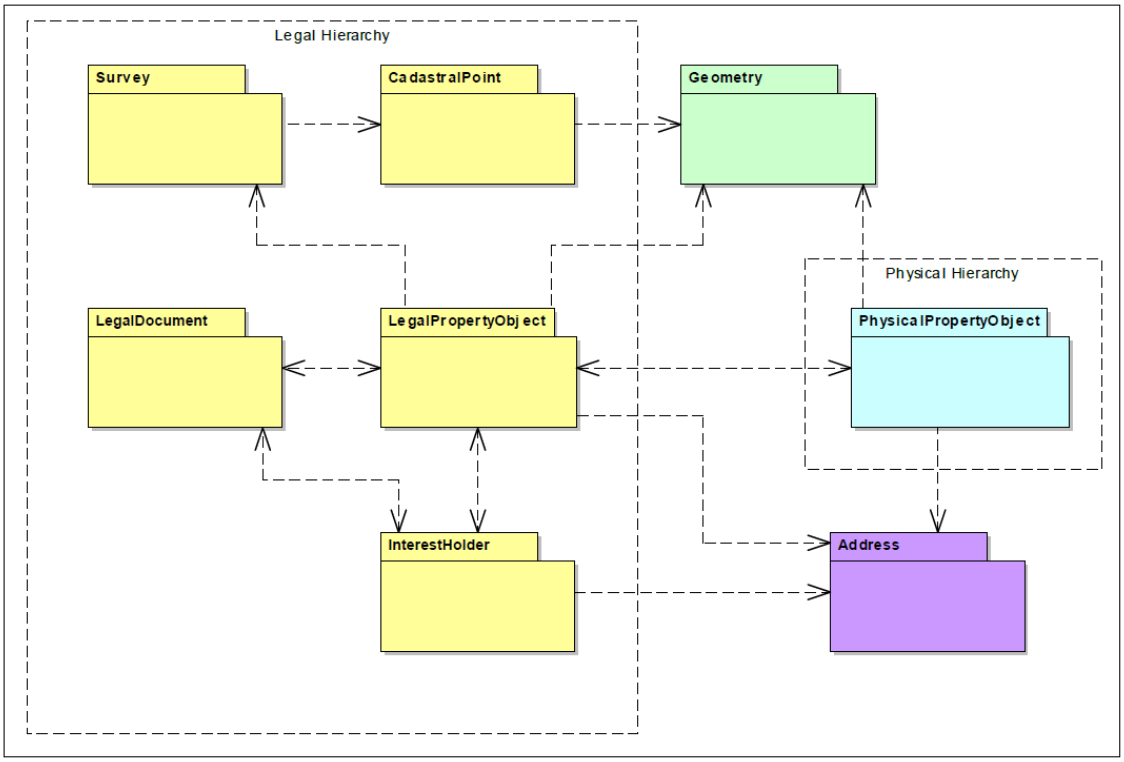


Figure 6.19 Conceptual Model of the 3DCDM model

6.4 CHAPTER SUMMARY

This chapter covered the first and second step of the data-modelling development cycle, business analysis and conceptual data modelling, for developing the 3DCDM model.

Requirements and data elements of the 3D cadastre were specified in the business analysis step. Need for digital 3D data, multi-purpose 3D cadastre (which requires both legal and physical objects), different methods of 3D data acquisition (using coordinated cadastral marks, architectural plans), representing all possible interests including land use, maintaining interest holder personal information and the detailed information which is currently kept in volume folios or other legal documents, supporting various 3D primitives to maintain geometrical/topological requirements, providing accurate and reliable data for 3D titling system, and maintain temporal information were identified as the main requirements of the users of the 3D cadastres.

In addition to the recognition of the users' requirements, the main data elements of 3D cadastres were identified to reveal the potential objects of the 3D cadastral data model and assist re-engineering data models to respond to the users' requirements. They are: 3D right object, 3D physical object, interest holder, title, surveying information, survey plan, and architectural plan information.

Obviously, the requirements of various users are different. The 3DCDM model supports the main elements and requirements; however, investigation of requirements should be extended to better meet the needs of user communities in each jurisdiction.

Furthermore, three underlying principles have been proposed in this section. These principles are:

- Principle 1: 2D land parcel is no longer the most effective building block of cadastres in the dense urban populated areas. It is superseded by 3D parcel.

- Principle 2: The 3D cadastral data model should not only accommodate 3D RRRs (legal objects); the data model should also represent the physical counterparts of legal objects.

- Principle 3: The 3D cadastral data model should support semantics to facilitate interoperability between legal and physical objects.

These principles are used to be as foundation to design and develop 3DCDM model in this research. As a result of the second principle, 3DCDM model was developed based on two different hierarchies: legal and physical.

Finally, the conceptual model of 3DCDM was developed step by step using the main components of the core cadastral data model, utilising the concept of the Legal Property Object model, and applying the advanced principles of 3D cadastral data modelling. The logical model of the 3DCDM is represented in more detail in the following chapter.

CHAPTER 7 – LOGICAL DATA MODELLING OF THE 3DCDM

7 LOGICAL DATA MODELLING OF THE 3DCDM

7.1 INTRODUCTION

3DCDM model is a 3D cadastral data model, developed not only to manage stratified land rights, restrictions, and responsibilities (3D RRRs), it also models the physical counterparts of 3D legal objects to provide information that is needed for different applications, such as urban planning and 3D site management. 3DCDM model maintains each 2D or 3D legal object as a LegalPropertyObject and links it to its relevant physical object. 3DCDM model supports semantics in class, attribute and association levels, as well as in a spatial level. Every legal and physical object is spatially constructed using geometrical objects, and is semantically enriched using specified classes.

3DCDM model is implemented as an application schema of the Geography Markup Language 3 (GML3), version GML3.2.1, the extendible international standard for spatial data exchange and encoding issued by the Open Geospatial Consortium (OGC) and the ISO TC211. The OGC recommended Geography Markup Language (GML), an XML dialect that is specifically designed to solve most issues in geospatial data interoperability (Aien, 2005).

In this chapter, the logical data model of 3DCDM model is presented as the third step of 3D cadastral data modelling. The data model is developed based on the ISO 191** standards and UML modelling language is used to specify the data model. Use of this model facilitates implementation of 3D cadastres and increases its usability for different applications.

7.2 3DCDM HIERARCHIES AND COMPONENTS

3DCDM model is composed of two hierarchies: legal and physical. However, they are connected to each other through the associations between their subclasses. 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 componenet of 3DCDB, 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 componenets: PhysicalPropertyObject, Building, Land, Tunnel, UtilityNetwork, and Terrain. 3DCDM model supports the combination of different legal and physical components to provide more comprehensive cadastral model (Figure 7.5).

Furthermore, 3DCDM model is developed based on Geography Markup language (GML3.2.1). 3DCDM model inherits GML3's specifications. GML3.2.1 supports most of the 3DCDM's general and spatial requirements. GML 3.2.1 maintains wide variety of spatial reference systems; it has a rich geometric model, and provides essential attributes to develop the 3DCDM model (Figure 7.5).

Different components and classes of the 3DCDM model are represented in the next section in detail.

UML classes are represented in different colours, in order to enhance the readability of the 3DCDM UML diagrams. The following colouring pattern is applied:

- Light brown: classes that belong to the root model of 3DCDM (Figure 7.1).

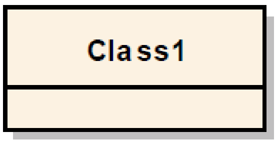


Figure 7.1: Light brown colour class demonstrating 3DCDM root model features

- Yellow: classes that belong to the legal hierarchy (Figure 7.2)

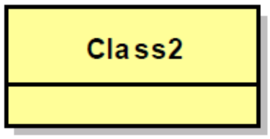


Figure 7.2: Yellow colour class demonstrating 3DCDM's legal hierarchy features

- Blue: classes that belong to the physical hierarchy (Figure 7.3)

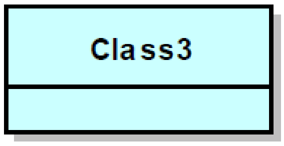


Figure 7.3: Blue colour class demonstrating 3DCDM's physical hierarchy features

- Green: GML features and its geometrical primitives (Figure 7.4)

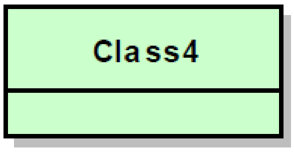


Figure 7.4: Green colour class demonstrating 3DCDM's GML features

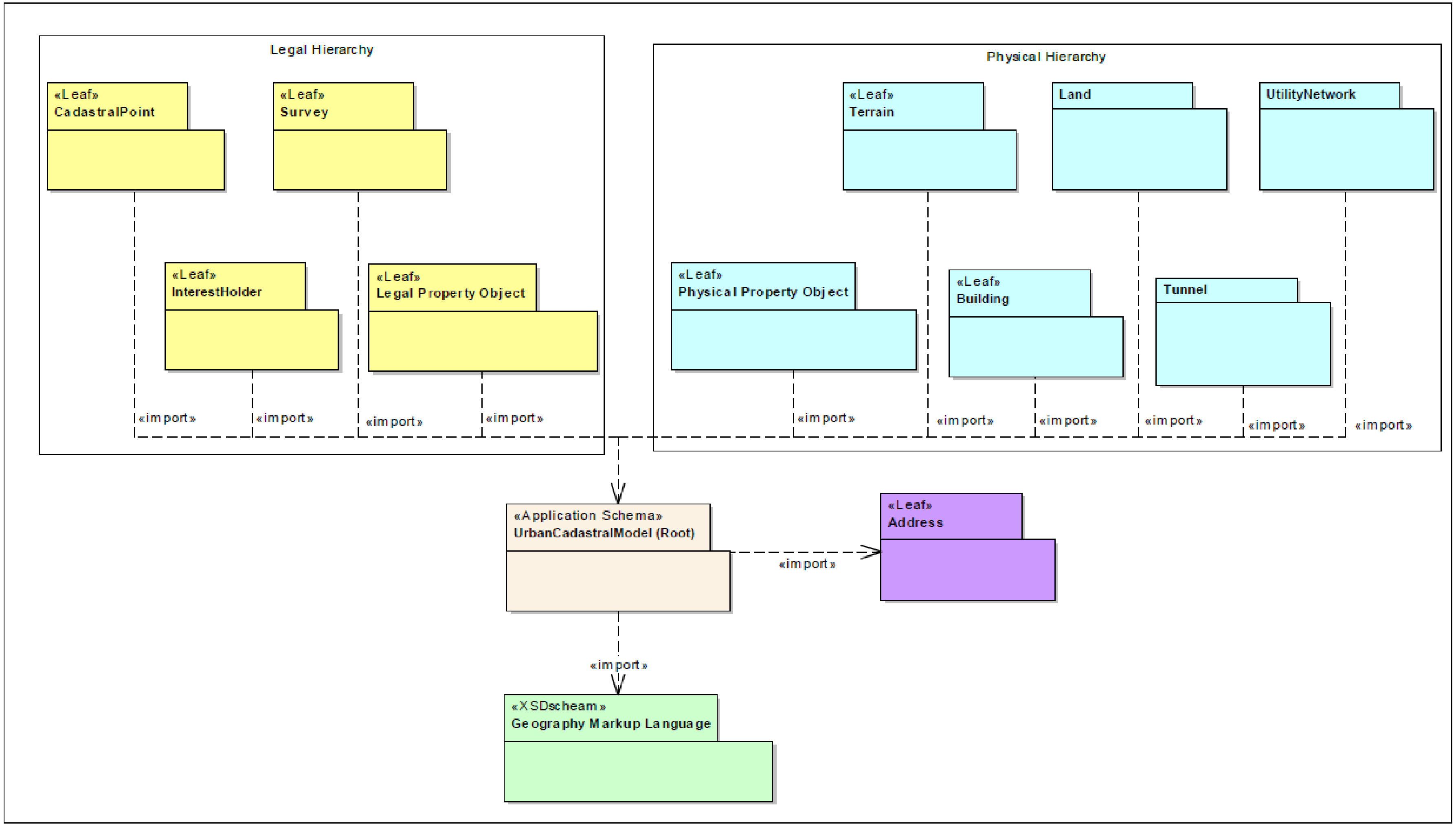


Figure 7.5: Separate models and hierarchies of the 3DCDM

7.3 3DCDM GEOMETRY MODEL

The geometry model of 3DCDM is based on the geometry model of Geographic Markup Language (GML3.2.1). GML follows the specification of standard ISO 19107 'Spatial schema' (ISO19107, 2005). GML represents 3D geometry according to the well-known Boundary Representation (Foley et al., 1995). There is a geometrical primitive for each dimension: *Point* for a zero-dimensional object, *Curve* for a one-dimensional, *Surface* for two-dimensional objects, and *Solid* for three-dimensional objects. A solid is bounded by surfaces and a surface by curves (Portele, 2007).

Combined geometries can be aggregates, complexes or composites of primitives. For an aggregate, the spatial relationship between primitives is not defined. They may be disjoint, touching, or overlapping. GML provides a special aggregate for each dimension, a *MultiPoint*, a *MultiCurve*, a *MultiSurface*, and a *MultiSolid*. On the contrary, a complex is topologically structured. Complex elements must be disjointed and must not overlap. They must be topologically connected along their boundaries. A composite is a special complex that can only contain elements of the same dimension. A composite can be a *CompositeCurve*, *CompositeSurface*, and a *CompositeSolid* (ISO19107, 2005).

The Geometry model contains the various classes for coordinate geometry (ISO19107, 2005). All of these classes through the root class inherit an optional association to a coordinate reference system. The geometry package has several internal packages that separate primitive geometric objects, aggregates and complexes, which have a more elaborate internal structure than simple aggregates (Portele, 2007). Figures 6.16, 6.17, and 6.18 show the 3DCDM geometry model.

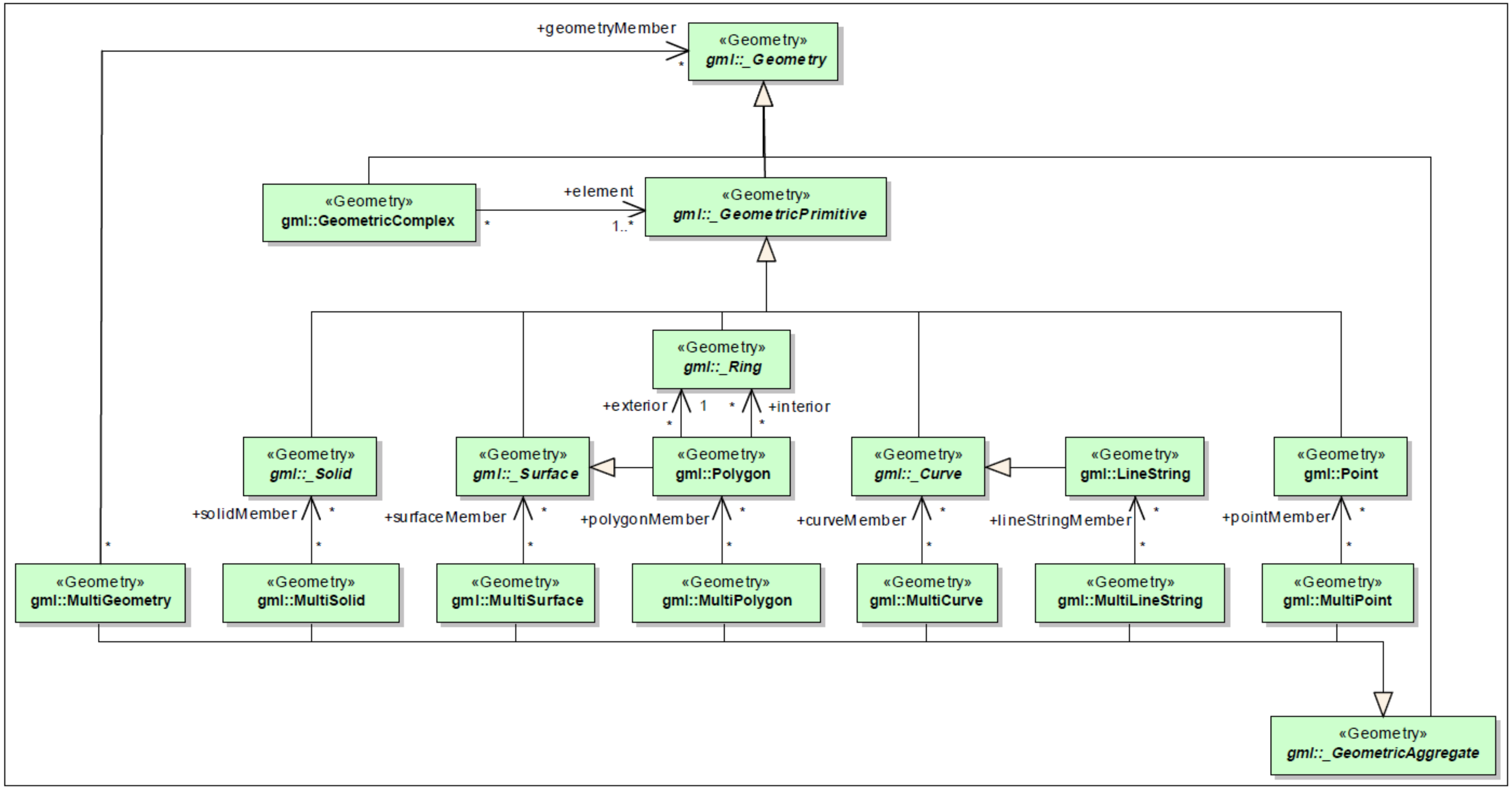


Figure 7.6: 3DCDM Geometry Model - Part 1 (profile of GML3.2.1)

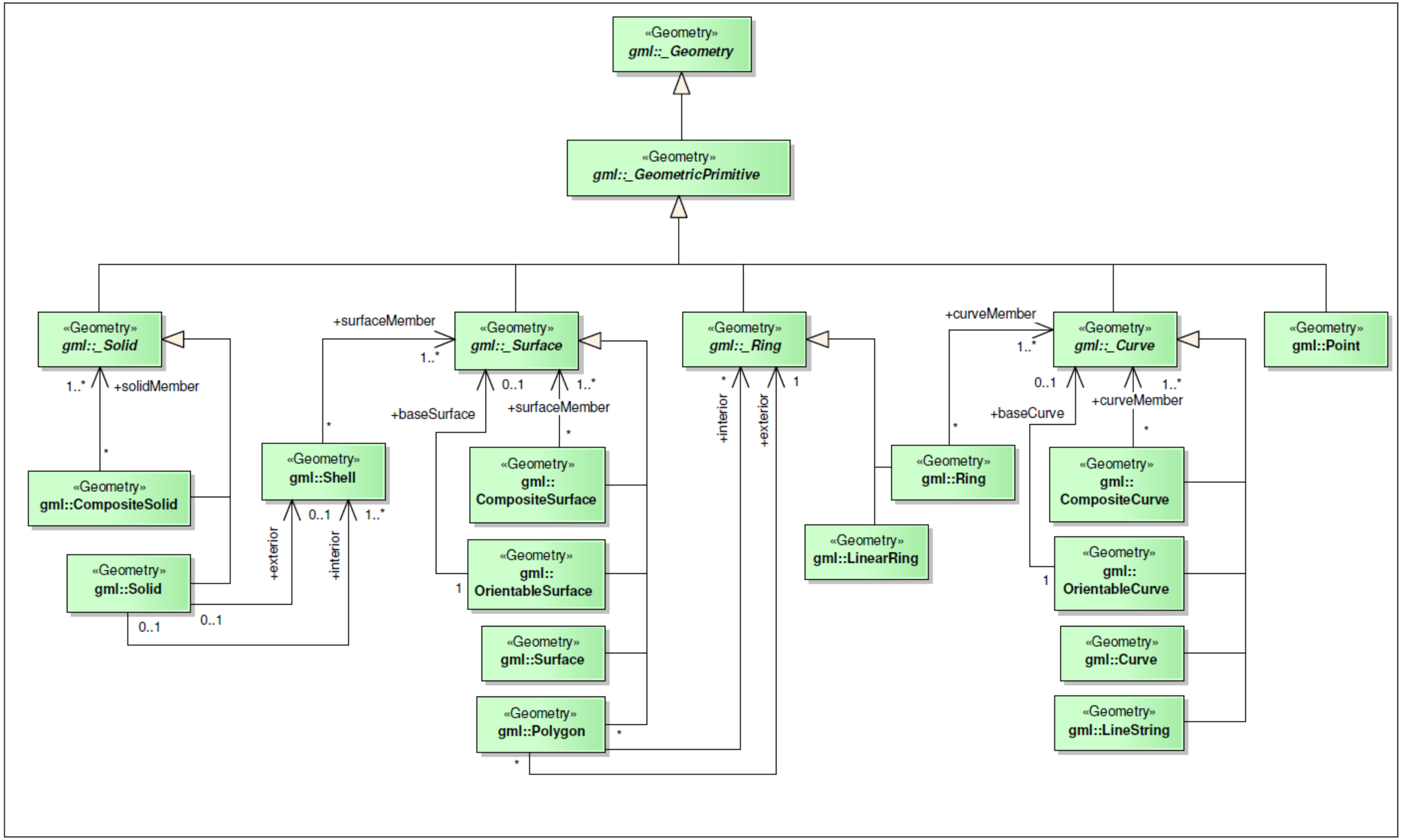


Figure 7.7: 3DCDM Geometry Model - Part 2 (profile of GML3.2.1)

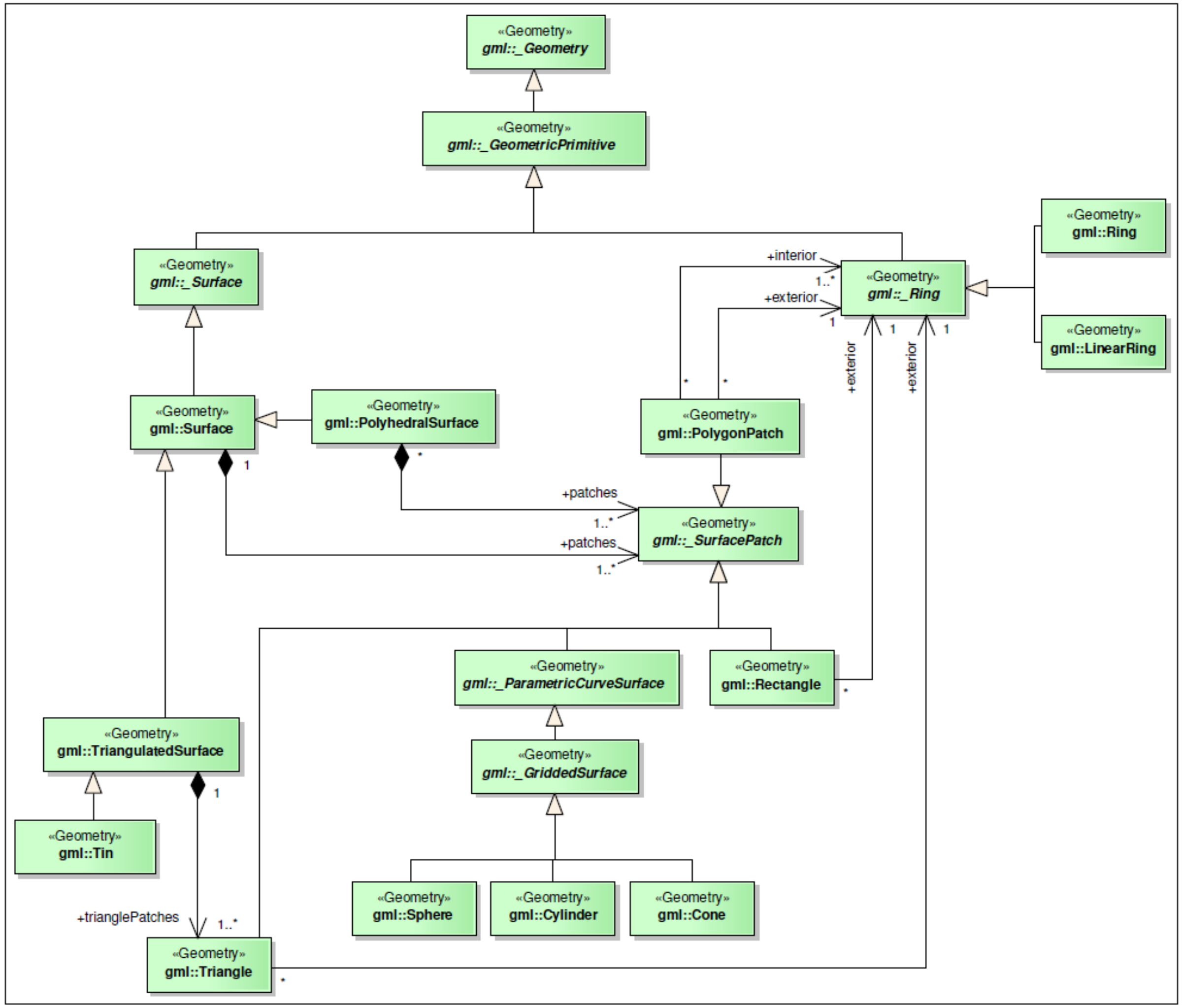


Figure 7.8: 3DCDM Geometry Model – Part 3 (profile of GML3.2.1)

Geometry model's main elements are introduced below (ISO19107, 2005):

_GeometricPrimitive (Figure 7.6) is the abstract root class of the geometric primitives. It is a geometric object that is not decomposed further into other primitives in the system.

_GeometricAggregates (Figure 7.6) gather geometric objects.

GeometricComplex (Figure 7.6) is a collection of geometrically disjointed, simple *_GeometricPrimitives*. *GeometricComplex* shall be used in application schemas where the sharing of geometry is important, such as in the use of computational topology.

Orientable primitives (Figure 7.6) are those that can be mirrored into new geometric objects in terms of their internal local coordinate system. For curves, the orientation reflects the direction in which the curve is traversed. For surfaces, the orientation reflects from which direction the local coordinate system can be viewed as right-handed, the 'top' or the surface being the direction of the completing z-axis that form a right-handed system. When used as a boundary surface, the bounded solid is 'below' the surface. The orientation of points and solids has no immediate geometric interpretation in 3-dimensional space.

Point (Figure 7.7) is the basic data type for a geometric object consisting of one and only one point.

Curve (Figure 7.7) is the basis for 1D geometry. Curves are continuous, connected, and have a measurable length in terms of the coordinate system. A curve is composed of one or more curve segments, the curve segments are connected to one another, with the end point of each segment except the last being the start point of the next segment in the segment list.

LineString (Figure 7.7) consists of sequences of line segments. They consist of two distinct DirectPositions, the *startPoint* and *endPoint*) joined by a straight line.

Surface (Figure 7.7) is a subclass of *_GeometricPrimitive* and is the basis for 2D geometry. The orientation of the surface chooses 'up' and 'down' direction through the choice of upward normal. If the surface is the boundary of a solid, the ‘up’ direction is usually outward.

SurfacePatch (Figure 7.8) defines a homogeneous portion of a *Surface*. Each *SurfacePatch* shall be mostly in GM_Surface.

A GM_PolyhedralSurface (Figure 7.8) is a *Surface* composed of polygon surfaces (*PolygonPatch*) connected by their common boundary curves.

Polygon (Figure 7.7) is a surface patch that is defined by a set of boundary curves.

TriangulateSurface (Figure 7.8) is a subclass of *Surface* that is composed only of triangles (*Triangle*).

Solid (Figure 7.7), a subclass of *_GeometricPrimitive* is the basis for 3D geometry. The extent of a solid is defined by the boundary surfaces.

7.4 3DCDM ROOT MODEL

The 3DCDM root model comprises of core features and components of the 3DCDM. All other models are connected to the root. This component of the 3DCDM must be realised in the implementation phase of the data model. The root model consists of two legal and physical hierarchies and it provides the opportunity for the user to choose one of or both hierarchies. The UML diagram in Figure 7.9 illustrates 3DCDM’s root model.

As mentioned previously, 3DCDM is an application schema for Geography Markup language (GML3.2.1). Therefore, 3DCDM inherits GML3’s specifications. GML3.2.1 supports most of the 3DCDM’s general and spatial requirements. GML 3.2.1 maintains a wide variety of spatial reference systems; it has a rich geometry model, and provides essential attributes such as *gml:id* (unique id) and names to define the required features.

3DCDM’s root model consists of gml:*_Feature*, gml;*_FeatureCollection*, *UrbanCadastralModel*, *Application*, *MericUnit*, *CadastralModel*, *_CadastralObject*, *UrbanModel*, and *_UrbanObject*.

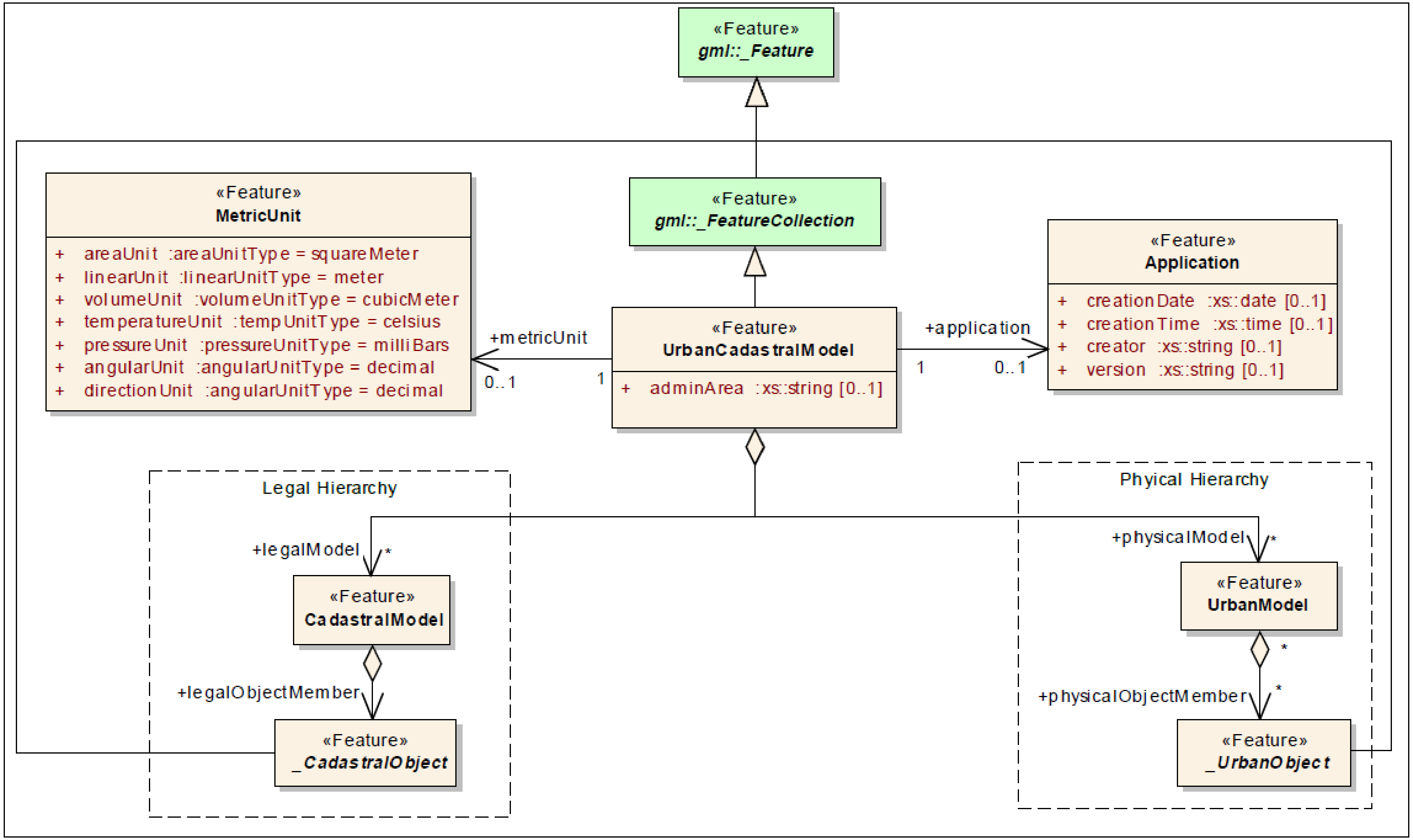


Figure 7.9: UML diagram of 3DCDM Root model

7.4.1 gml:_Feature

This abstract element serves as the head of a substitution group, which may contain any elements. This may be used as a variable in the construction of content models. Abstract *gml:_Feature* may be thought of as 'anything that is a GML feature' and may be used to define variables or templates in which the value of a GML property is 'any feature' (Portele, 2007).

GML defines features distinct from geometry objects. A feature is an application object that represents a physical entity, e.g. a building, a river, or a person. A feature may or may not have geometric aspects. A geometry object defines a location or region instead of a physical entity, and hence is different from a feature (Brink et al., 2011).

7.4.2 gml:_FeatureCollection

Abstract class *gml:_FeatureCollection* is a collection of GML Features together with an Envelope (which bounds the set of Features), and is a collection of properties that apply to the *gml:_FeatureCollection* and an optional list of Spatial Reference System Definitions. A *gml:_FeatureCollection* can also contain other *gml:_FeatureCollection*, provided that the Envelope of the bounding *gml:_FeatureCollection* bounds the Envelopes of all of the contained *gml:_FeatureCollection* (Brink et al., 2011). It is a subclass of the GML class *gml:_Feature*.

7.4.3 UrbanCadatralModel

UrbanCadatralModel is the base class of all components in 3DCDM data model. Its *adminArea* attribute enables specification of the area where the cadastral model is created. *UrbanCadatralModel* is a subclass of the GML class *gml:_Feature*. *UrbanCadatralModel* consists of zero or more *CadastralModel* and *UrbanModel* (figure 7.9). Table 7.1 lists all attributes of the class *UrbanCadatralModel*.

Table 7.1: Attributes of the class UrbanCadatralModel

Attribute	Detail	Value type	Multiplicity
adminArea	The name of the jurisdiction or area	string	0..1

Therefore, it inherits the metadata property such as Coordinate Reference System (CRS) and general properties such as *name* from its superclass.

7.4.4 Application

This class provides further metadata about the application that created the Model. Table 7.2 lists all attributes of the class *Application*.

Table 7.2: Attributes of the class Application

Attribute	Detail	Value type	Multiplicity
creationDate	The date of creation of the model	date	0..1
creationTime	The time of creation of the model	time	0..1
creator	The identifier of the author of the model	string	0..1
version	The version of the model	string	0..1

7.4.5 MetricUnit

This class provides further metadata about the measurement units. Table 7.3 lists all attributes of the class *MetricUnit*.

Table 7.3: Attributes of the class MetricUnit

Attribute	Detail	Value type	Multiplicity
areaUnit	The measurement unit of area	areaUnitType:squareMeter	1
linearUnit	The measurement unit of line	linearUnitType:meter	1
volumeUnit	The measurement unit of volume	volumeUnitType:cubicMeter	1
temperatureUnit	The measurement unit of area	tempUnitType:celsius	1
pressureUnit	The measurement unit of temperature	pressureUnitType:milliBars	1

angularUnit	The measurement unit of angle	angularUnitType:decimal	1
directionUnit	The measurement unit of direction	angularUnitType:decimal	1

7.4.6 CadastralModel

This class is the first class of the 3DCDM's legal hierarchy. It forms the cadastral model.

7.4.7 _CadastralObject

Abstract class *_CadastralObject* is the base class of all legal classes in the 3DCDM. It is a subclass of *gml:_Feature* and therefore inherits the attributes of superclass *gml:_Feature*. *_CadastralObject* subclasses are *LegalPropertyObject*, *InterestHolder*, *Survey*, *CadastralPoints* (Figure 7.10).

7.4.8 UrbanModel

This class is the first class of the 3DCDM's physical hierarchy. It forms the urban model.

7.4.9 _UrbanObject

Abstract class *_UrbanObject* is the base class of all physical classes in the 3DCDM. It is a subclass of *gml:_Feature* and therefore inherits the attributes of superclass *gml:_Feature*. *_UrbanObject* subclasses are *_PhysicalPropertyObject*, *Terrain*. *Building*, *Land*, *Tunnel*, *_UtilityNetwork*, and *PhysicalPropertyObject* are subclasses of Abstract class *_UrbanObject* (Figure 7.10).

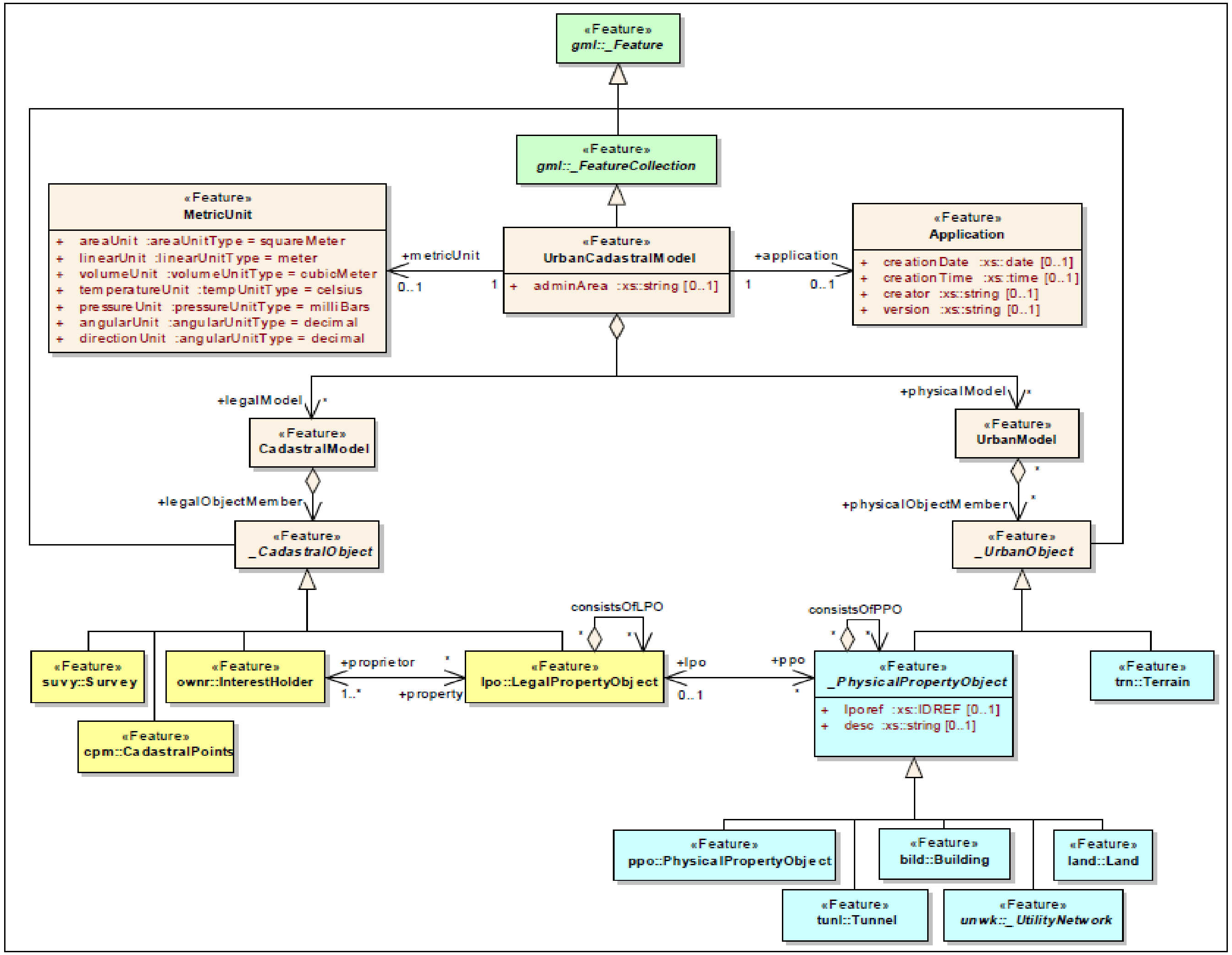


Figure 7.10: The UML diagram of 3DCDM Root model and the legal and physical model subclasses.

7.5 3DCDM LegalPropertyObject MODEL

Every legal object is represented as a *LegalPropertyObject* in 3DCDM model. Figure 7.11 represents the attributes and associated classes of the class *LegalPropertyObject*. Each *LegalPropertyObject* class is associated with zero or more *_PhysicalPropertyObjects* such as *Building*, *Tunnel*, *UtilityNetwork* and *Land*. It has one or more *InterestHolders*. Each *LegalPropertyObject* acquires its legal information through its associated *LegalDocument*.

Ownership space is more of a conceptual concept. Physical structures such as fences, hedges, or walls are used to demarcate and represent the ownership boundaries. However, the legal spaces (boundaries) are not always equal to their corresponding physical spaces (physical boundaries). For example, legal boundaries are usually bigger than the physical boundaries in villa units. Furthermore, in some cases such as airspace, the legal space cannot be defined by physical boundaries. For these reasons, the creation of Legal Property Object in 3D cadastres is needed. 3DCDM supports creation of *LegalPropertyObject* using GML geometry objects. If the *LegalPropertyObject* is a 2D land parcel, it can be created *using gml:MultiCurve* or gml: *MultiSurface*. And if it is a 3D parcel, it can be created using *gml:MultiSurface* or *gml:_Solid* (Figure 7.11).

However, if the *LegalPropertyObject* is equal to its physical counterpart and can be defined using physical objects; 3DCDM provides various boundary types such as *WallSurface*, *CeilingSurface*, *FloorSurface*, *RoofSurface*, *SlabSurface*, *SuspendedCeilingSurface*, *FloorJoistSurface* to semantically define the boundary of a *LegalPropertyObject*.

Another method to semantically define the legal boundaries in 3DCDM is to use the *LegalPropertyObject*'s attribute *ppoRef* to reference a physical object.

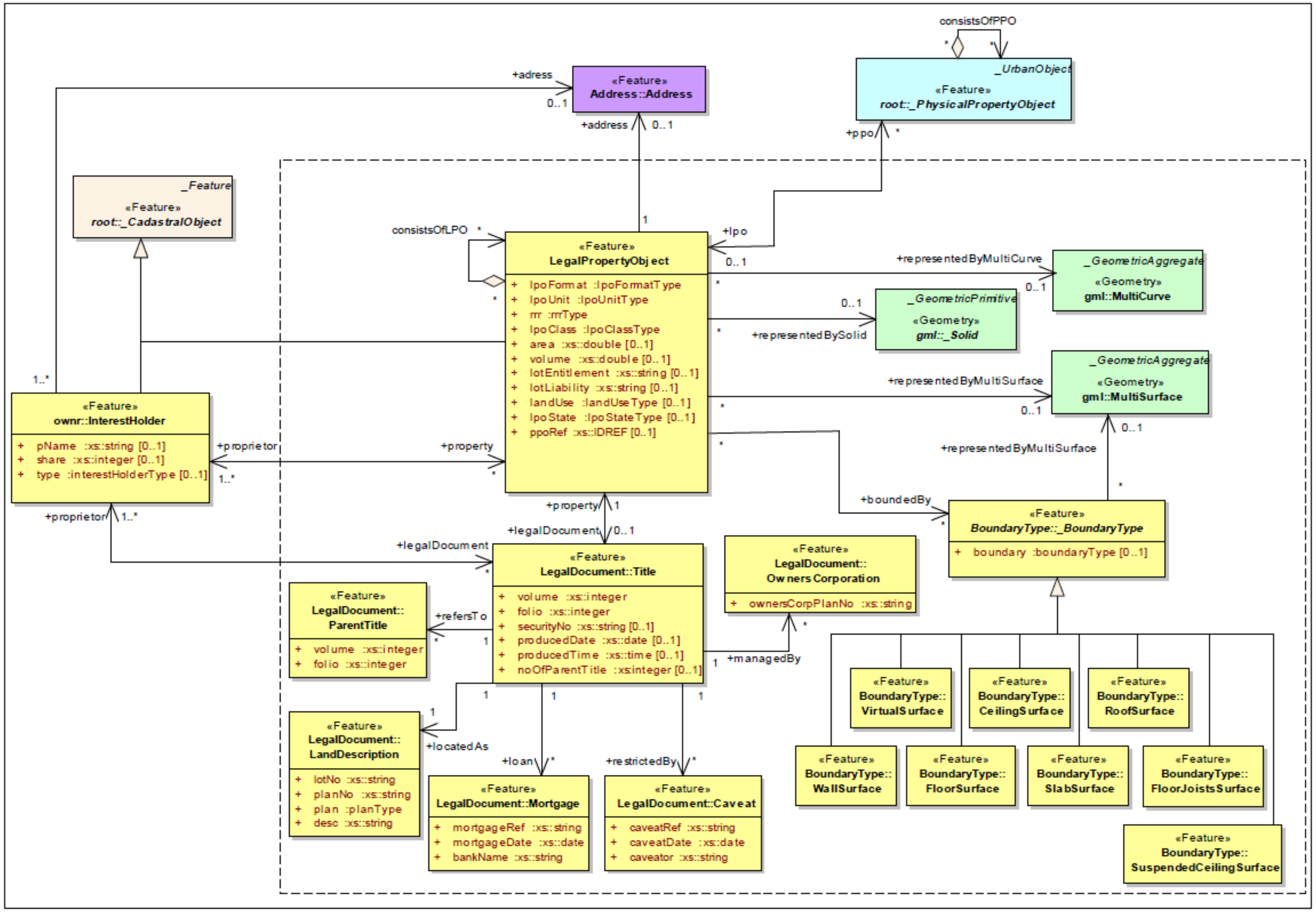


Figure 7.11: The UML diagram of 3DCDM LegalPropertyObject model.

7.5.1 LegalPropertyObject

This class represents all types of legal objects such land parcel, 3D parcel, ownership, easement, common property. *LegalPropertObject* is a subclass of *_CadastralObject* and therefore it inherits the attributes of superclass *_CadastralObject*. *LegalPropertObject* is associated to the class *Address* that identifies the physical address of the *LegalPropertObject*. Table 7.4 lists all attributes of the class *LegalPropertyObject*.

Table 7.4: Attributes of the class LegalPropertyObject

Attribute	Detail	Value type	Multiplicity
lpoFormat	Defines the format of *LehgalPropertyObject*	lpoFormatType	1
lpoUnit	Defines the unit of *LehgalPropertyObject*	lpoUnitType	1
rrr	Defines the type of *LehgalPropertyObject*	rrrType	1
lpoClass	Defines the class of *LehgalPropertyObject*	lpoClassType	1
area	The date of the *LehgalPropertyObject*	double	0..1
volume	The volume of the *LehgalPropertyObject*	double	0..1
lotEntitlement	Define the entitlement portion of the *LehgalPropertyObject*	string	0..1
lotLiability	Define the liability portion of the *LehgalPropertyObject*	string	0..1
landUse	The land use of the *LehgalPropertyObject*	landUseType	0..1
lpoState	Defines the state of *LehgalPropertyObject*	lpoStateType	0..1
ppoRef	Refers to the corresponding physical object	IDREF	0..1

7.5.2 Code Lists for the LegalPropertyObject

Code lists are used to describe different enumeration. They represent the possible examples of the values. They are open and can be extended. Figure 7.12 shows the code lists for the *LegalPropertyObject*.

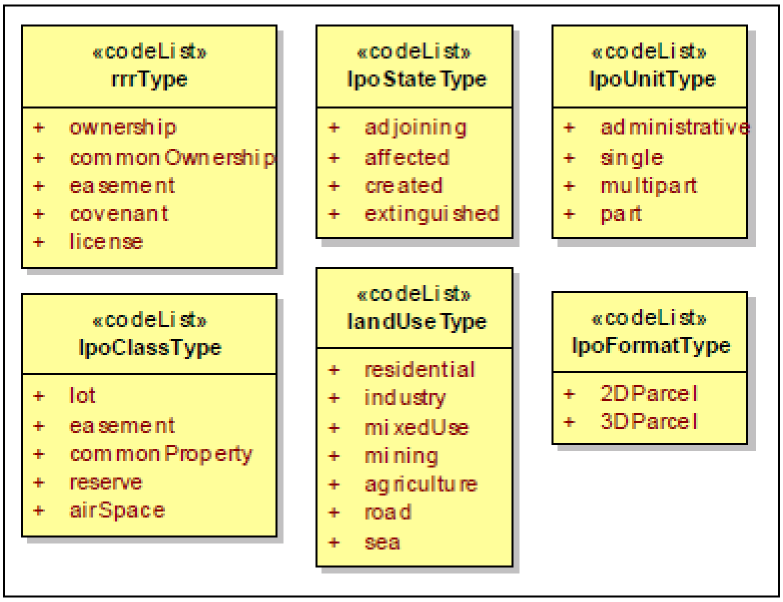


Figure 7.12: The Code lists for the LegalPropertyObject class

7.5.3 LegalDocument: Title

Each *LegalPropertyObject* is associated with one legal document such as a title, a deed, an agreement if it has been registered. It is also possible to identify the *LegalPropertyObject* through the legal documents (Figure 7.11). Table 7.5 lists all attributes of the class *Title*.

Table 7.5: Attributes of the class Title

Attribute	Detail	Value type	Multiplicity
volume	Defines the unique volume number of the title	integer	1
folio	Defines the unique folio number of the title	integer	1
securityNo	Defines the unique security number	string	0..1

	of the title		
producedDate	The date, title is produced	date	0..1
producedTime	The time, title is produced	time	0..1
noOfParentTitle	Defines the number of parent title	integer	0..1

7.5.4 LegalDocument: ParentTitle

Each *Title* can be associated to zero or more *ParentTitle* (Figure 7.11). Table 7.6 lists all attributes of the class *ParentTitle*.

Table 7.6: Attributes of the class ParentTitle

Attribute	Detail	Value type	Multiplicity
volume	Defines the unique volume number of the title	integer	1
folio	Defines the unique folio number of the title	integer	1

7.5.5 LegalDocument: LandDescription

LegalPropertyObject's specification is described in class *LegalDescription* (Figure 7.11). Table 7.7 lists all attributes of the class *Title*.

Table 7.7: Attributes of the class LandDescription

Attribute	Detail	Value type	Multiplicity
lotNO	Defines the lot number in the title	string	1
planNo	Defines the plan number in the title	string	1
plan	Specifies the type of plan	planType	1
desc	Describes the lot in the title	string	1

Figure 7.13 shows the code list for *planType*.

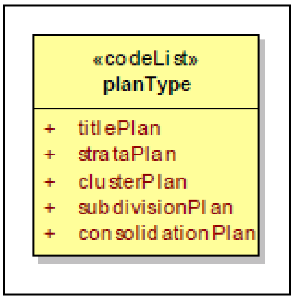


Figure 7.13: The Code list for the LandDescription

7.5.6 LegalDocument: Mortgage

Title can be associated to the class *Mortgage* (Figure 7.11). *Mortgage* is registered as a restriction in the *Title*. Table 7.8 lists all attributes of the class *Mortgage*.

Table 7.8: Attributes of the class Mortgage

Attribute	Detail	Value type	Multiplicity
mortgageRef	Defines the Reference number of the mortgage	string	1
mortgageDate	The date of the mortgage	date	1
bankName	Bank name which provided the mortgage	string	1

7.5.7 LegalDocument: Caveat

Title can be associated to the class *Caveat* (Figure 7.11). *Caveat* is registered as a restriction in the *Title*. Table 7.9 lists all attributes of the class *Caveat*.

Table 7.9: Attributes of the class Caveat

Attribute	Detail	Value type	Multiplicity
caveatRef	Defines the Reference number of the caveat	string	1
ceveatDate	The date of the caveat	date	1
caveator	The name of caveator	string	1

7.5.8 LegalDocument: OwnersCorporation

Title can be associated to the class *OwnersCorporation* (Figure 7.11). *OwnersCorporation* is registered to manage the property when it has common areas. Table 7.10 lists all attributes of the class *OwnersCorporation*.

Table 7.10: Attributes of the class OwnersCorporation

Attribute	Detail	Value type	Multiplicity
ownersCorpPlanNo	Defines the owners corporation plan number	string	1

7.5.9 BoundaryType:_BoundaryType

Abstract class *_BoundaryType* contains different subclasses to semantically define the *LegalPropertyObject*. They are *VirtualSurface*, *WallSurface*, *CeilingSurface*, *FloorSurface*, *RoofSurface*, *SlabSurface*, *SuspendedCeilingSurface*, *FloorJoistsSurface* (Figure 7.11). Table 7.11 lists all attributes of the class *_BoundaryType*. *VirtualSurface* is used when the legal boundary does not correspond with a physical object.

Table 7.11: Attributes of the class _BoundaryType

Attribute	Detail	Value type	Multiplicity
boundary	Defines the boundary type that is used spatially define the *LegalPropertyObject*	boundaryType	1

Figure 7.14 shows the code list for *boundaryType*.

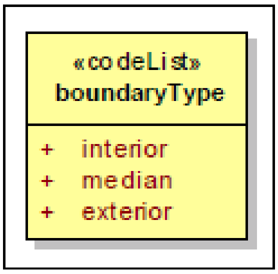


Figure 7.14: The Code list for the BoundaryType

7.6 3DCDM INTERSETHOLDER MODEL

This model maintains information about the land interest holder. This model has only one class, which is class *InterestHolder*.

7.6.1 InterestHolder

InterestHolder can be a person, group, or an organisation who have certain rights (RRRs) over a particular 3D spatial space. An *InterestHolder* can be associated with the classes *LegalPropertyObject* and *Title*. *InterestHolder* is a subclass of *_CadastralObject* and therefore it inherits the attributes of abstract superclass *_CadastralObject* (Figure 7.15). *InterestHolder* is associated to the class *Address,* which identifies the living address of the interest holder.

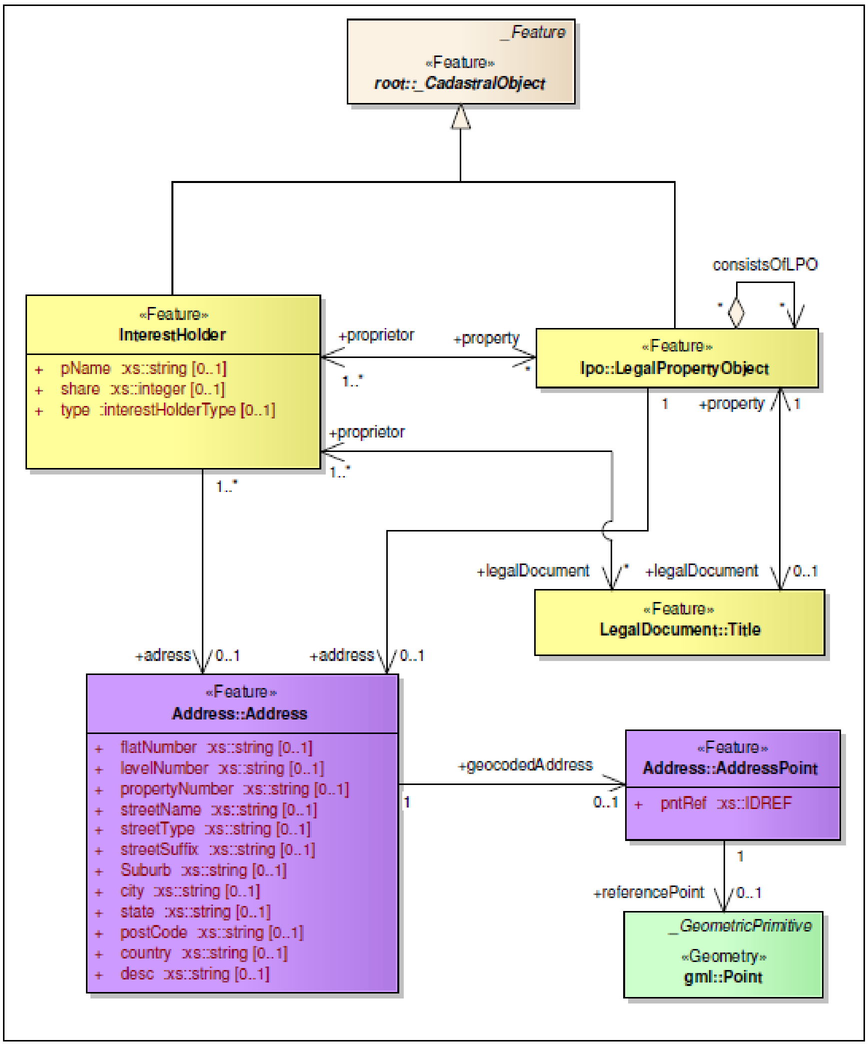


Figure 7.15: The UML diagram of 3DCDM InterestHolder model.

Table 7.12 lists all attributes of the class *InterestHolder*.

Table 7.12: Attributes of the class InterestHolder

Attribute	Detail	Value type	Multiplicity
pName	Defines the name of the interest holder	string	0..1
share	Specifies the share of ownership	integer	0..1
type	The type of the interest holder	interestHolderType	0..1

Figure 7.16 shows the code list for *InterestHolder*.

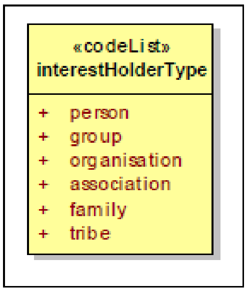


Figure 7.16: The Code list for the InterestHolder

7.7 3DCDM SURVEY MODEL

The Survey model contains 7 classes that describe technical and administrative information of surveying and surveyor, which is required in cadastral applications.

7.7.1 Survey

The class *Survey* is the main class of the model and holds general information of surveying (Figure 7.18). *Survey* is a subclass of *_CadastralObject* and therefore it inherits the attributes of superclass *_CadastralObject*. Table 7.13 lists all attributes of the classes below:

Table 7.13: Attributes of the class Survey

Attribute	Detail	Value type	Multiplicity
jurisdiction	The jurisdiction in which the survey is undertaken	string	0..1
legislation	The legislation that the survey is undertaken	string	0..1
perposeOfSurvey	Specifies surveying purpose	string	0..1
surveyDate	The date of survey	date	1
surveyFormat	Specifies the survey format	surFormatType	0..1
method	Specifies the survey method	surMethod	0..1
fieldNoteRef	A reference for surveying	string	0..1

	field note		
desc	The description of the survey	string	0..1

7.7.2 Surveyor

The class *Surveyor* maintains the details of any surveyor who participated in the survey (Figure 7.18). Table 7.14 lists all attributes of the classes below:

Table 7.14: Attributes of the class Surveyor

Attribute	Detail	Value type	Multiplicity
name	Surveyor's name	string	0..1
regNumber	Surveyor's registration number	integer	0..1
surveyorFirm	The name of surveying firm	double	0..1

7.7.3 SetupInstrument

The class *SetupInstrument* retains setting-up information of surveying instruments on surveying points (Figure 7.18). Table 7.15 lists all attributes of the classes below:

Table 7.15: Attributes of the class SetupInstrument

Attribute	Detail	Value type	Multiplicity
setupID	The setup point id	string	0..1
stationName	The setup point name	integer	0..1
instrumentHeight	The height of the instrument	double	0..1

7.7.4 SetupPoint

The class *SetupPoint* refers to the setup points of the cadastral points (Figure 7.18). Table 7.16 lists all attributes of the classes below:

Table 7.16: Attributes of the class SetupPoint

Attribute	Detail	Value type	Multiplicity
pntRef	Refers to a unique point	IDREF	0..1

7.7.5 ObservationGroup

Surveying observations are maintained in the class *ObservationGroup* and its associated classes *RedHorizontalArcObservation* and *RedHorizontalLineObservation* (Figure 7.18). Table 7.17 lists all attributes of the classes below:

Table 7.17: Attributes of the class ObservationGroup

Attribute	Detail	Value type	Multiplicity
id	Specifies an identifier to the observation group	ID	1

7.7.6 RedHorizontalArcObservation

The class *RedHorizontalArcObservation* holds horizontally reduced observations for arcs (Figure 7.18). Table 7.18 lists all attributes of the classes below:

Table 7.18: Attributes of the class RedHorizontalArcObservation

Attribute	Detail	Value type	Multiplicity
name	The name of the observation	ID	1
desc	The description for the observation	string	0..1
purpose	The purpose of the observation	purposeType	1
setupID	Refers to an instrument setup id	IDREF	1
targetSetupID	Refers to an instrument setup id	IDREF	1
chordAzimuth	The bearing of the chord line	double	1
radius	The radius of the curve	double	1
length	The horizontal distance of the	double	1

	curve		
rot	Direction of the rotation (cw: clockwise, ccw:anticlockwise)	cc or ccw	1
arcAzimuthAccuracy	Bearing accuracy	double	0..1
arcLengthAccuracy	distance	double	0..1
fieldNoteRef	Refers to the surveying field note	string	0..1

7.7.7 RedHorizontalLineObservation

The class *RedHorizontalLineObservation* holds horizontally reduced observations for lines (Figure 7.18). Table 7.19 lists all attributes of the classes of the class *RedHorizontalLineObservation*.

Table 7.19: Attributes of the class RedHorizontalLineObservation

Attribute	Detail	Value type	Multiplicity
name	The name of the observation	ID	1
desc	The description for the observation	string	0..1
purpose	The purpose of the observation	purposeType	1
setupID	Refers to an instrument setup id	IDREF	1
targetSetupID	Refers to an instrument setup id	IDREF	1
azimuth	The bearing of the line	double	1
horizDistance	The horizontal distance of the line	double	1
azimuthAccuracy	Bearing accuracy	double	0..1
distanceAccuracy	distance	double	0..1
fieldNoteRef	Refers to the surveying field note	string	0..1

7.7.8 Code Lists for the Survey Model

Figure 7.17 shows code lists for the Survey model. They represent the possible examples of the values.

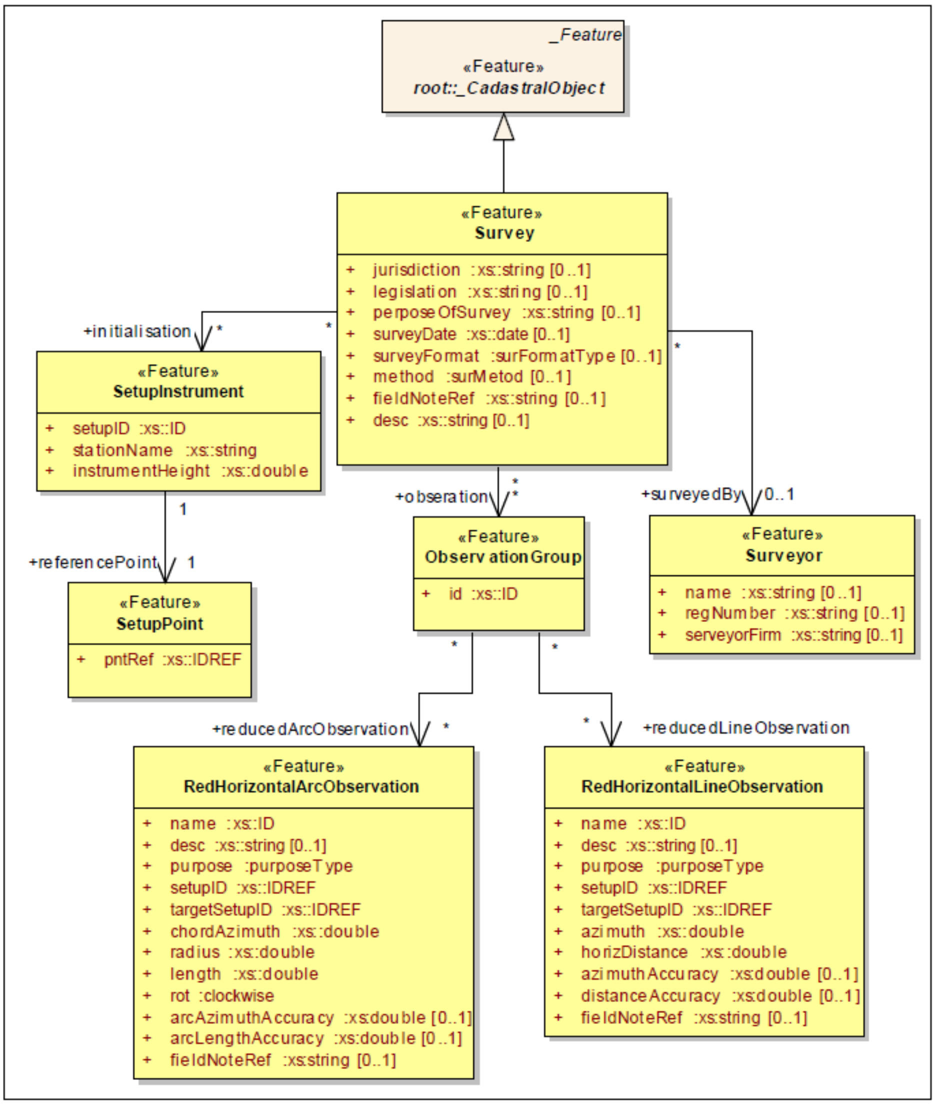


Figure 7.17: The UML diagram of 3DCDM Survey model.

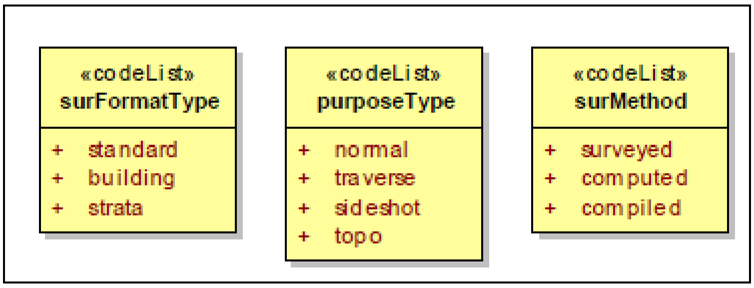


Figure 7.18: The Code list for the Survey

7.8 3DCDM CADASTRALPOINTS MODEL

As surveying of permanent marks is very important for surveyors, the 3DCDM model keeps the elements related to the survey permanent marks as the *CadastralPoints* model. Permament marks are placed in the ground by monuments (e.g. pin, peg) during the survey process. Survey points can be 2D or 3D. The *CadastralPoints* model contains 2 main classes that describe the information of survey points (Figure 7.20).

7.8.1 CadastralPoints

The class *CadastralPoints* is a subclass of *_CadastralObject* and therefore it inherits the attributes of abstract superclass *_CadastralObject*. The class *CadastralPoints* is a group of survey points (Figure 7.20). Table 7.20 lists all attributes of the class *CadastralPoints*.

Table 7.20: Attributes of the class CadastralPoints

Attribute	Detail	Value type	Multiplicity
name	The name of the group point	string	0..1
desc	A description of the points	integer	0..1

7.8.2 CadastralPoint

The class *CadastralPoints* consists of one or more *CadastralPoint*, which is created using *gnl:point* geometry object (Figure 7.20). Table 7.21 lists all attributes of the class below:

Table 7.21: Attributes of the class CadastralPoint

Attribute	Detail	Value type	Multiplicity
name	The name of the point	ID	1
state	The state type of the point	stateType	1
monument	The monument type of the point	monumentType	0..1

7.8.3 Code Lists for the CadastralPoints Model

Figure 7.19 shows the code list for the *cadastralPoints*.

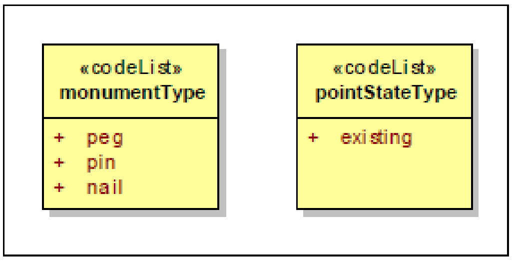


Figure 7.19: The Code list for the CadastralPoints model

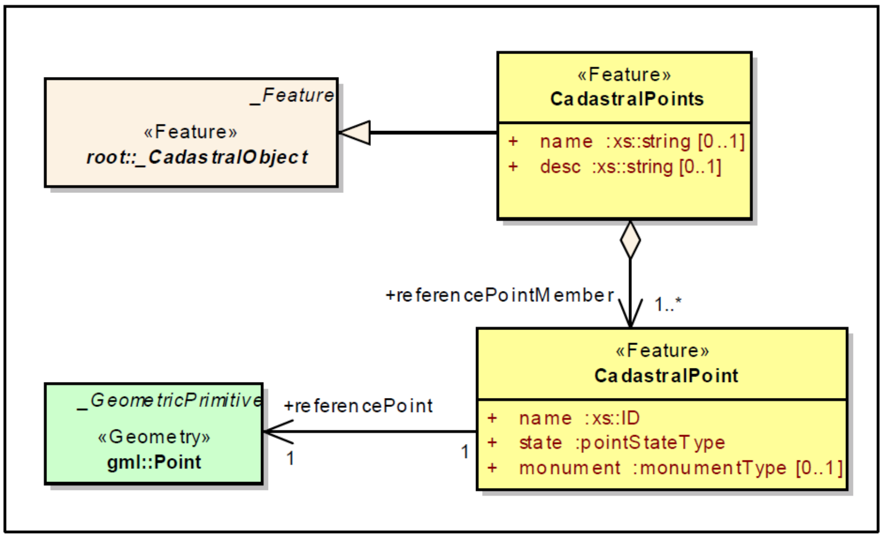


Figure 7.20: The UML diagram of 3DCDM CadastralPoints model.

7.9 3DCDM BUILDING MODEL

3DCDM supports the *Building* model. 3DCDM model allows users to create the building models and then link it to its legal counterparts. The *Building* model is located in the physical hierarchy of the 3DCDM model. The *Building* model has an abstract superclass *_PhysicalPropertyObject* that is associated with zero or one *LegalPropertyObject*. The abstract class *_PhysicalPropertyObject* is a subclass of *_UrbanObject* and therefore it inherits the attributes of abstract superclass *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. The *Building* model can be created through four main subclasses. They are class *Building*, abstract class *_BuildingPart*, class *Space*, and abstract class *_StructuralComponent* (Figure 7.21).

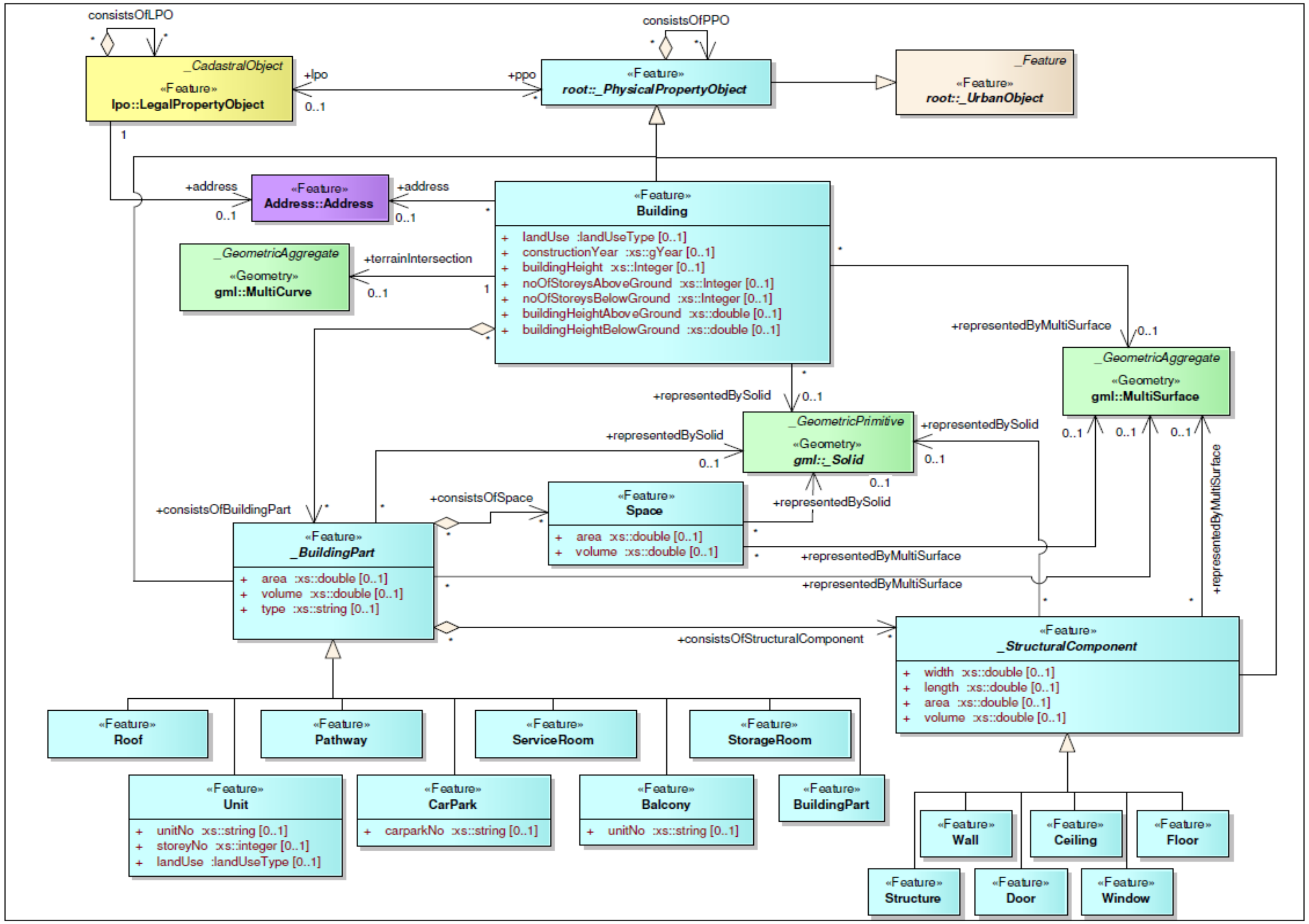


Figure 7.21: The UML diagram of 3DCDM Building model.

7.9.1 Building

The class *Building* describes the physical shape (without internal components) of a building. The class *Building* is a 3D object and is created using *gml:_Solid* or *gml:MultiSurface* geometry object. The class *Building*'s set of attributes help to almost envisage the shape of the building. In 3DCDM model, the intersection lines of a building and terrain surface is represented using *gml:MultiCurve*. The class *Building* is associated to the class *Address* to specify the physical address of each building. A building is decomposed into different building parts (Figure 7.21). Table 7.22 lists all attributes below:

Table 7.22: Attributes of the class Building

Attribute	Detail	Value type	Multiplicity
landUseType	Specifies the land use of the building	landUseType	0..1
constructionYear	The year of the building's construction	gYear	0..1
buildingHeight	The height of the building	integer	0..1
noOfStorysAboveGround	Number of storeys above ground	integer	0..1
noOfStorysBelowGround	Number of storeys below ground	integer	0..1
buildingHeightAboveGround	Building's height above ground	double	0..1
buildingHeightBelowGround	Building's height below ground	double	0..1

7.9.2 _BuildingPart

The abstract class *_BuildingPart* and its specialisations such as *Unit*, *CarPark*, *Roof*, *Pathway*, *ServiceRoom*, *StorageRoom*, *Balcony*, and *BuildingPart* (any type of building part) are used to model the internal sections of a building (Figure 7.21).

Each _ *BuildingPart* can be represented directly using *gml* geometric objects or can be represented by various structural components and spaces. Figure 7.22 illustrates how different building parts such as four units and one pathway of a building is constructed using structural components such as walls, floors, and ceilings and also spaces.

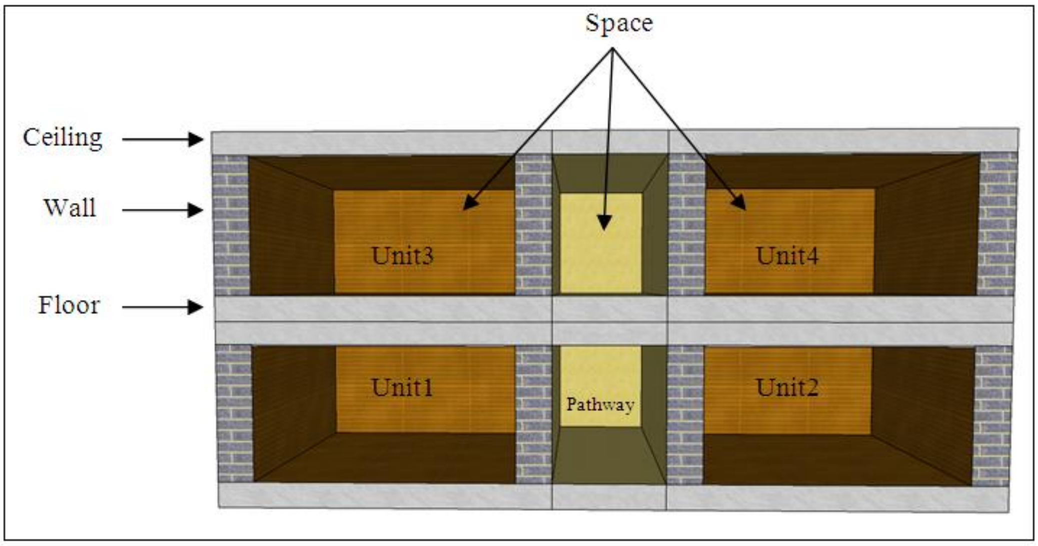


Figure 7.22: Example of a building model consists of structural components and spaces.

The abstract class *_BuildingPart* is a subclass of *_PhysicalPropertyObject* and therefore it inherits the attributes of abstract superclass *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. Table 7.23, 7.24, 7.25, and 7.26 list all attributes of the abstract class *_BuildingPart*, *Unit*, *CarPark*, and *Balcony* respectively.

Table 7.23: Attributes of the class _BuildingPart

Attribute	Detail	Value type	Multiplicity
area	The area of BuildingPart	double	0..1
volume	The volume of BuildingPart	double	0..1
type	Specifies the type of BuildingPart when it not clear	string	0..1

Table 7.24: Attributes of the class Unit

Attribute	Detail	Value type	Multiplicity
unitNo	The number of units	string	1
storeyNo	The number of storeys in which the unit is located	integer	1
landUseType	Specifies the land use of the building	landUseType	0..1

Table 7.25: Attribute of the class CarPark

Attribute	Detail	Value type	Multiplicity
carparkNo	The number of carparks	string	0..1

Table 7.26: Attribute of the class Balcony

Attribute	Detail	Value type	Multiplicity
unitNo	The number of units which the balcony belongs to	string	0..1

7.9.3 Space

Each building part can be created using zero or more spaces. The class *Space* defines the internal volumetric space of a *_BuildingPart*. *Space* is a 3D object and can be represented using *gml:MultiSurface* or *gml:_Solid* (Figure 7.21). Table 7.27 lists all attributes of the class *Space*.

Table 7.27: Attributes of the class Space

Attribute	Detail	Value type	Multiplicity
area	The area of space	double	0..1
volume	The volume of space	double	0..1

7.9.4 _StructuralComponent

Each building part can be created using zero or more *_StructuralComponent*. The abstract class *_StructuralComponent* defines the structures that are used to create the *_BuildingPart*. Each *_StructuralComponent* can be represented using *gml:MultiSurface* or *gml:_Solid*. The abstract class *_StructuralComponent's* semantically defines the type of building structure (Figure 7.21). They are *Wall*, *Ceiling*, *Floor*, *Door*, *Window*, and *Structure* (any type of structure such as a pile). The abstract class *_StructuralComponent* is a subclass of *_PhysicalPropertyObject* and therefore it inherits the attributes of abstract superclass *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. Table 7.28 lists all attributes of the class *_StructuralComponent*.

Table 7.28: Attributes of the class _StructuralComponent

Attribute	Detail	Value type	Multiplicity
width	The width of the structure	double	0..1
length	The length of the structure	double	0..1
area	The area of the structure	double	0..1
volume	The volume of the structure	double	0..1

7.9.5 Code Lists for the Building Model

Figure 7.23 shows the code list for the *Building* Model.

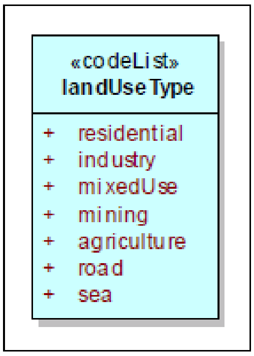


Figure 7.23: The Code list for the Building model

7.10 3DCDM LAND MODEL

3DCDM supports the *Land* model. Land model in 3DCDM model is used for 2D cadastral applications. In this model, it considers a physical object that legal entities will be attached to. The *Building* model has an abstract superclass *_PhysicalPropertyObject* that is associated with zero or one *LegalPropertyObject*.

7.10.1 Land

The class Land is a subclass of abstract class *_PhysicalPropertyObject* therefore it inherits the attributes of abstract superclasses *_PhysicalPropertyObject*, *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. The class *Land* is a 2D object and is created using *gml:MultiCurve* or *gml:MultiSurface* geometry object. The class *Land* is associated to the class *Address* to specify the physical address of each land (Figure 7.24).

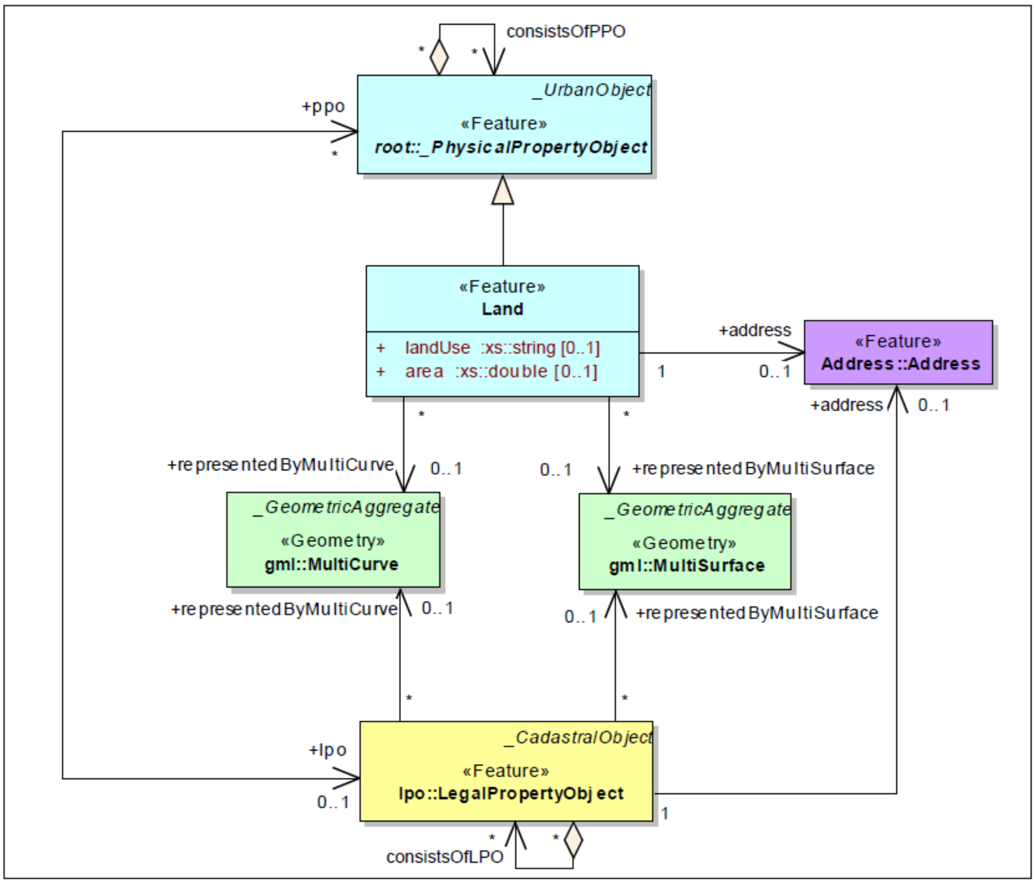


Figure 7.24: The UML diagram of 3DCDM Land model.

Table 7.29 lists all attributes of the class *Land* below:

Table 7.29: Attributes of the class Land

Attribute	Detail	Value type	Multiplicity
landUse	Specifies the land use of the land	string	0..1
area	The area of the structure	double	0..1

7.11 3DCDM TUNNEL MODEL

3DCDM supports the *Tunnel* model as an important urban object. 3DCDM model allows users to create the tunnel models and then link it to its legal counterparts. The *Tunnels* model such as *Building* and *Land* models is located in the physical hierarchy of the 3DCDM model. The *Tunnel* model has an abstract superclass *_PhysicalPropertyObject,* which is associated with zero or one *LegalPropertyObject*. The abstract class *_PhysicalPropertyObject* is a subclass of *_UrbanObject* and therefore it inherits the attributes of abstract superclass *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. The *Tunnel* model can be created through three main subclasses. They are class *Tunnel*, class *Space*, and abstract class *_StructuralComponent* (Figure 7.25).

7.11.1 Tunnel

The class *Tunnel* describes the physical shape (without internal components) of a tunnel. The class *Tunnel* is a 3D object and is created using *gml:_Solid* or *gml:MultiSurface* geometry object. In 3DCDM model, the intersection lines of a tunnel and terrain surfaces is represented using *gml:MultiCurve*. The class *Tunnel* is associated to the class *Address* to specify the physical address of a tunnel (Figure 7.25). Table 7.30 lists all attributes below:

Table 7.30: Attributes of the class Building

Attribute	Detail	Value type	Multiplicity
usage	Specifies the usage of the tunnel	string	0..1

constructionYear	The year of tunnel's construction	gYear	0..1
heightBelowGround	The depth of the tunnel below surface ground	double	0..1
width	The width of the tunnel	double	0..1
length	The length of the tunnel	double	0..1

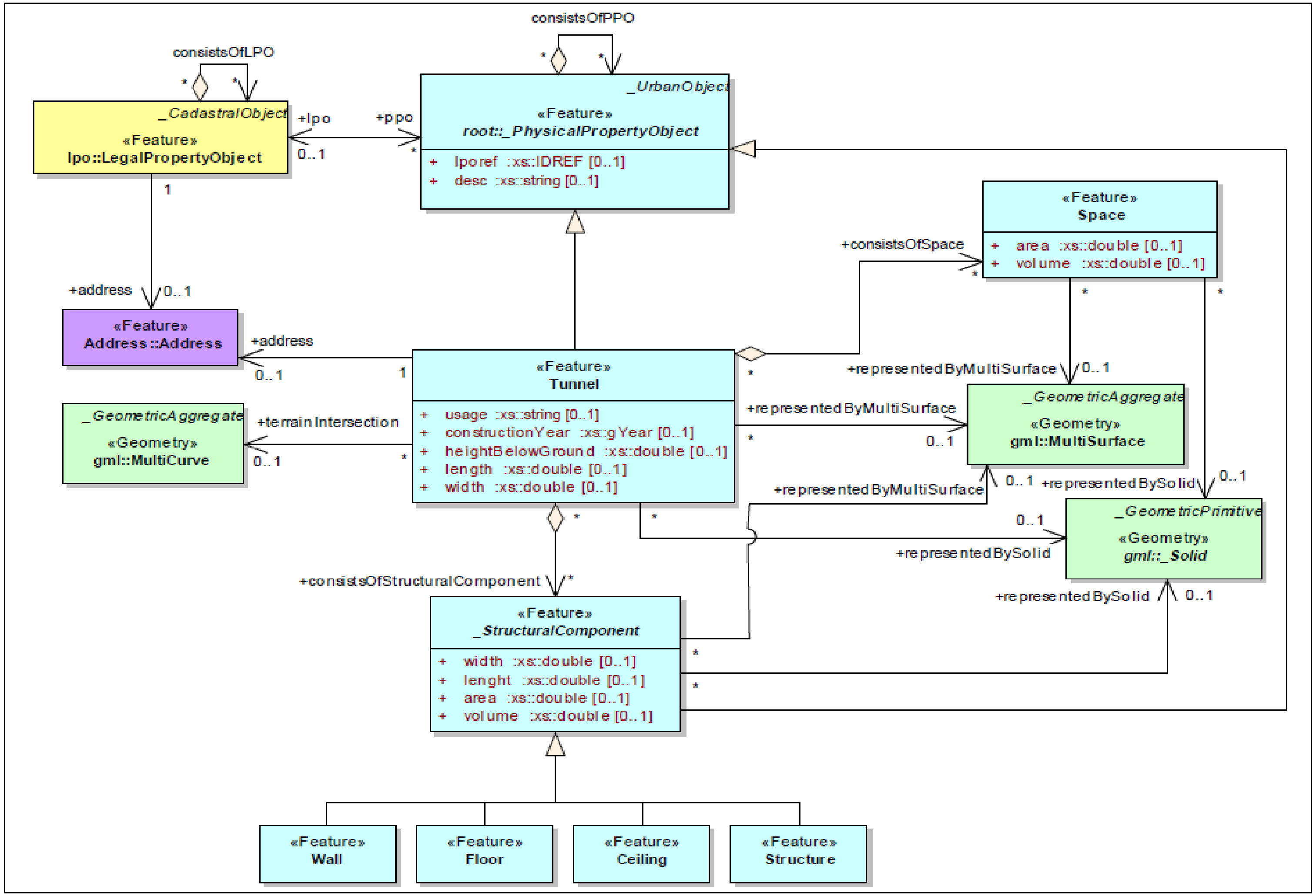


Figure 7.25: The UML diagram of 3DCDM Tunnel model.

7.11.2 Space

Each tunnel can be created using zero or more spaces. The class *Space* defines the internal volumetric space of a *Tunnel*. *Space* is a 3D object and can be represented using *gml:MultiSurface* or *gml:_Solid* (Figure 7.25). Attributes of the class *Space* in *Tunnel* model are similar to Attributes of the class *Space* in the *Building* model (see Table 7.27).

7.11.3 _StructuralComponent

Each tunnel can be created using zero or more *_StructuralComponent*. The abstract class *_StructuralComponent* in the *Tunnel* model is similar to the abstract class *_StructuralComponent* in *Building* model (see section 7.9.4). Also, Figure 7.26 illustrates how a tunnel consists of structures and a space.

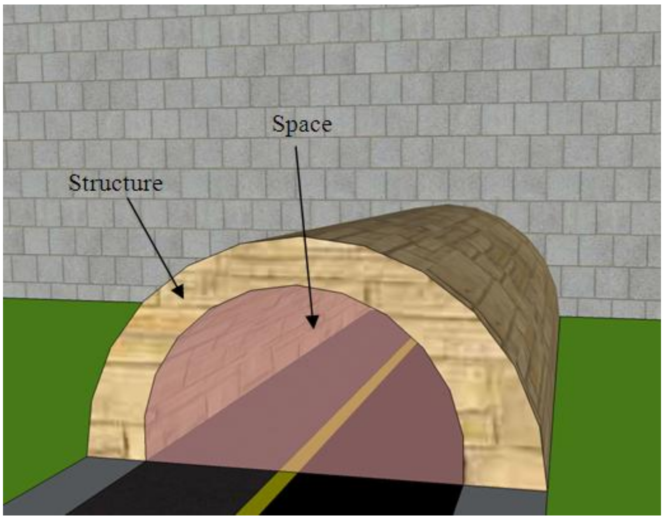


Figure 7.26: Example of a tunnel model consists of structural components and a space.

7.12 3DCDM UTILITYNETWORK MODEL

3DCDM supports the *UtilityNetwork* model. 3DCDM model allows users to create the utility network models and then link it to its legal counterparts. The *Tunnel* model has an abstract superclass *_PhysicalPropertyObject* that is associated with zero or one *LegalPropertyObject*. The *UtilityNetwork* model can be created through two main subclasses. They are abstract class *_UtilityNetwork* and class *NetworkComponent* (Figure 7.27).

7.12.1 _UtilityNetwork

The abstract class *_UtilityNetwork* and its specialisations such as *ElectricityNetwork*, *WaterNetwork*, *TelecommunicationNetwork*, and *WasteNetwork* are used to model the internal sections of a utility network. The class *_UtilityNetwork* is associated to the class *Address* to specify the physical address of a utility network (Figure 7.27).

Each *_UtilityNetwork* can be represented directly using *gml* geometric objects or can be represented by various network components. The abstract class *_UtilityNetwork* is a subclass of *_PhysicalPropertyObject* and therefore it inherits the attributes of abstract superclass *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. Table 7.31 lists all attributes of the abstract class *_UtilityNetwork below*:

Table 7.31: Attributes of the class _UtilityNetwork

Attribute	Detail	Value type	Multiplicity
length	The length of the network	double	0..1
constructionYear	The year of the network's construction	gYear	0..1
networkHeightBelowGround	The depth of the network below surface ground	double	0..1

7.12.2 NetworkComponent

Each utility network can be created using zero or more *NetworkComponent*. The class *NetworkComponent* defines the structures that are used to create the *_UtilityNetwork*. Each *NetworkComponent* can be represented using *gml:MultiCurve*, *gml:MultiSurface*, or *gml:_Solid* (Figure 7.27). The class *NetworkComponent* is a subclass of *_PhysicalPropertyObject* and therefore it inherits the attributes of abstract superclass *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. Table 7.32 lists all attributes of the class *below:*

Table 7.32: Attributes of the class NetworkComponent

Attribute	Detail	Value type	Multiplicity
material	The material of the network	string	0..1
length	The length of the network	double	0..1
width	The width of the network	double	0..1
area	The area of the network	double	0..1
volume	The volume of the network	double	0..1

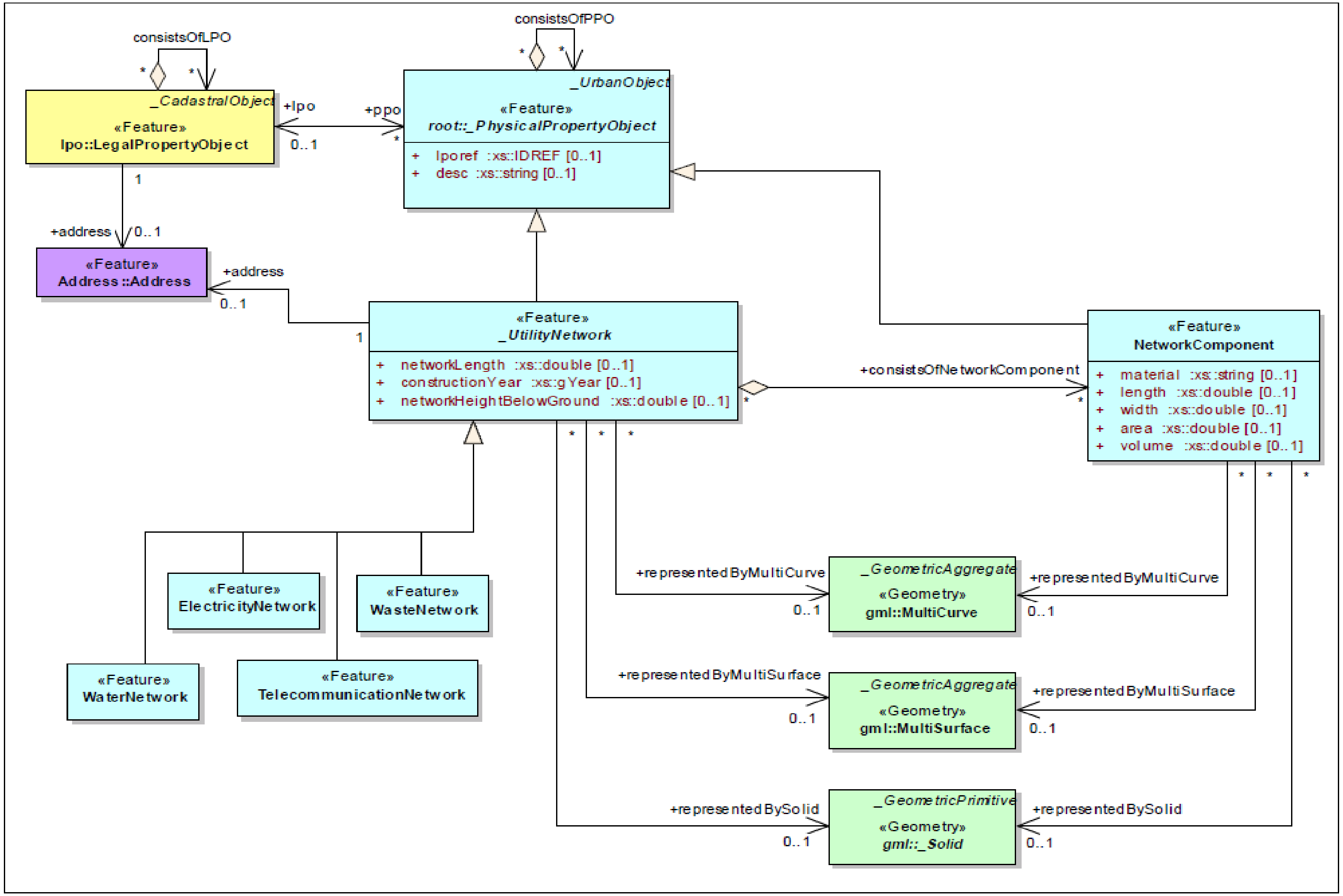


Figure 7.27: The UML diagram of 3DCDM UtilityNetwork model.

7.13 3DCDM PhysicalPropertyObject MODEL

In 3DCDM model, the *PhysicalPropertyObject* is designed to model unknown urban objects, which need to be created to link to their corresponding legal objects. If the physical property object were none of the existing physical models in the 3DCDM such as *Building*, *Land*, *Tunnel*, or *_UtilityNetwork* models, *PhysicalPropertyObject* model would be used to model the urban object. The *PhysicalPropertyObject* model has an abstract superclass *_PhysicalPropertyObject* that is associated with zero or one *LegalPropertyObject*. The *PhysicalPropertyObject* model has one subclass, that is the class *PhysicalPropertyObject* (Figure 7.28).

7.13.1 PhysicalPropertyObject

The class *PhysicalPropertyObject* is used to model any unknown urban object that is not included in the model. Each *PhysicalPropertyObject* can be represented directly using *gml* geometric objects. The class *PhysicalPropertyObject* is a subclass of *_PhysicalPropertyObject* and therefore it inherits the attributes of abstract superclass *_UrbanObject* and consequently inherits the attributes of abstract superclass *gml:_Feature*. The class *PhysicalPropertyObject* is associated to the class *Address* to specify the physical address of an urban object (Figure 7.28).

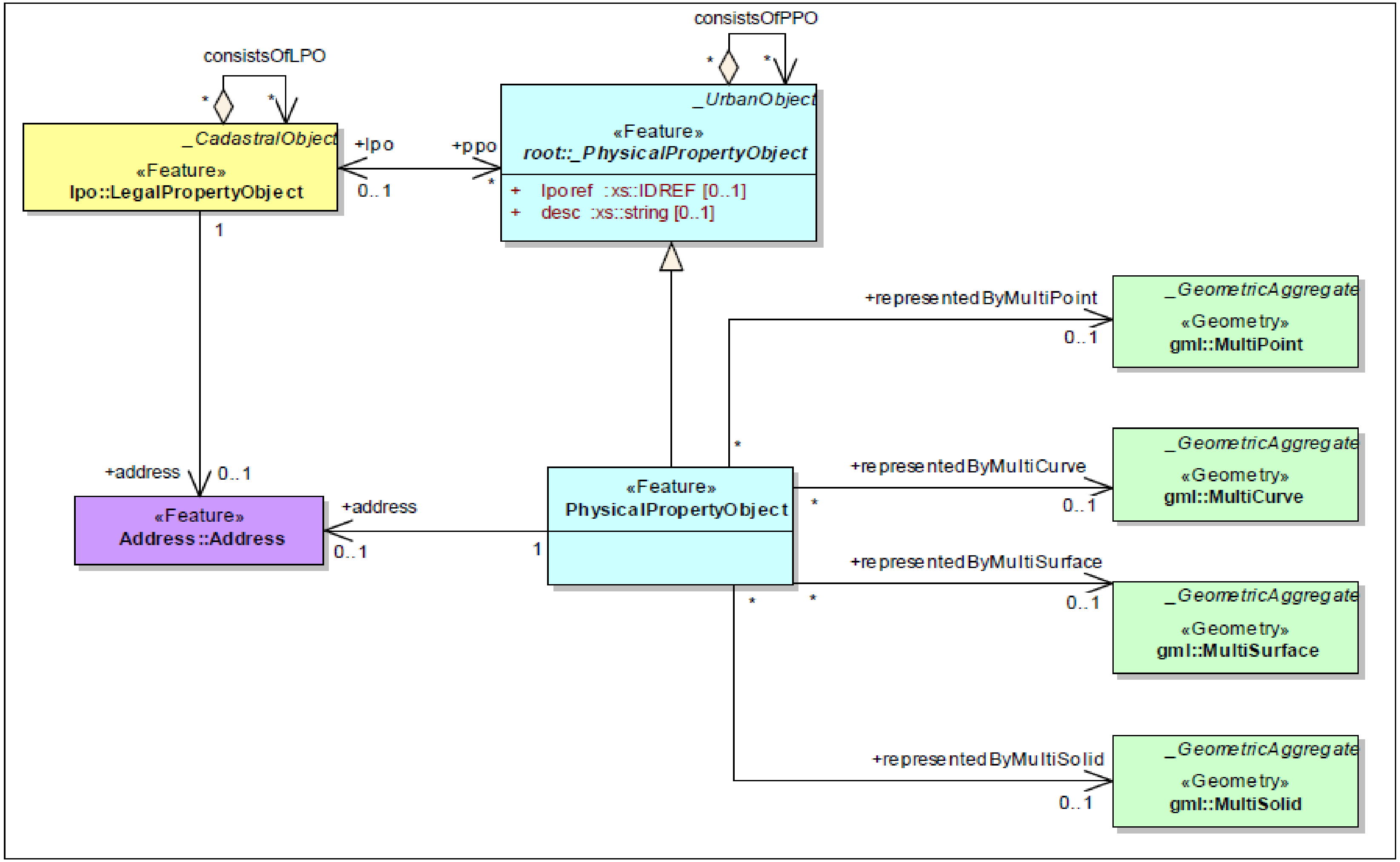


Figure 7.28: The UML diagram of 3DCDM PhysicalPropertyObject model.

7.14 3DCDM TERRAIN MODEL

Terrain or surface ground is an important part of the physical world. It is also an essential feature for cadastral applications. A combination of terrain and land ownership right objects provides more realistic representation of the legal world. 2.5D cadastres, representation of land parcels on a 3D ground surface and is a long term practice in the land administration domain (Stoter et al., 2004; Bydlosz, 2012). 3D cadastres, combination of 3D parcels with the terrain model will represent more realistic legal models and facilities to better understand the location and boundaries of land ownership objects, especially when they are located below the ground surface. 3DCDM supports the terrain model. Figure 7.29 illustrates the UML diagram of the terrain model in the 3DCDM.

7.14.1 Terrain

In 3DCDM the terrain is represented by the class *Terrain*. *Terrain* is subclasses of Abstract class *_UrbanObject* (Figure 7.29), and inherits all the corresponding attributes and associations.

7.14.2 TerrainSource

Terrain consists of one or more entities of class *TerrainSource*. *TerrainSource* are subclasses of Abstract class *_UrbanObject* (Figure 7.29), and inherits all the corresponding attributes and associations.

7.14.3 TIN

In 3DCDM, the terrain can be represented as a Triangulated Irregular Network (TIN). TIN is created using GML geometry class *gml:Tin* (Figure 7.29).

7.14.4 DEM

The terrain can be represented as a multiple 3D points or DEM in 3DCDM. DEM is created using GML geometry class *gml:MultiPoint* (Figure 7.29).

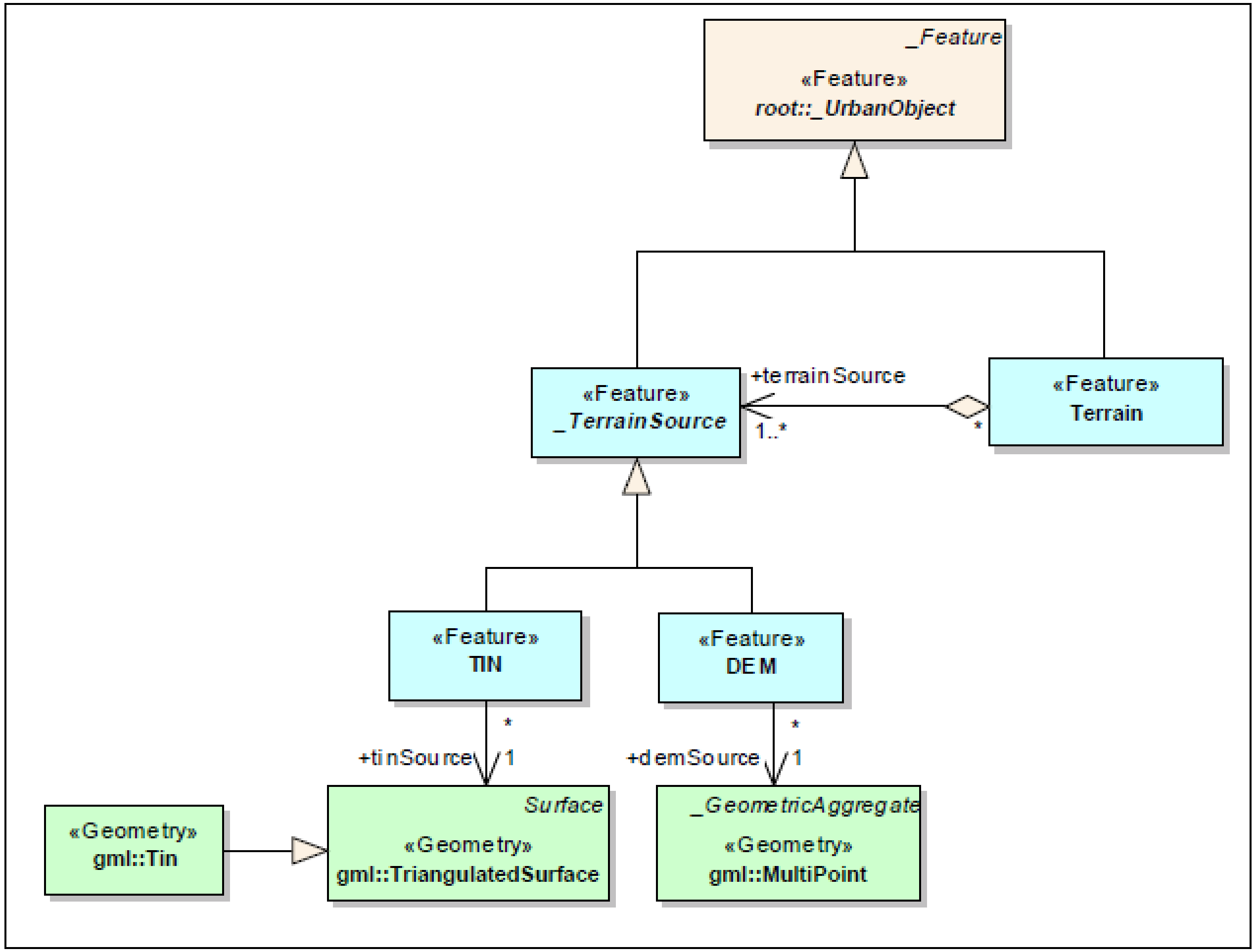


Figure 7.29: The UML diagram of 3DCDM terrain model.

7.15 CHAPTER SUMMARY

In this chapter, the logical model of the 3DCDM was presented as the third step of 3D cadastral data-modelling development cycle. The aim was to explore all elements and components of the 3DCDM model including its classes, attributes, and associations.

For this purpose, the package view of 3DCDM was presented at the first step to provide the big picture of 3DCDM's components. They are separated into two hierarchies in the 3DCDM model: legal and physical.

Then, 12 sub-models or modules of the 3DCDM were presented 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*.

Having separate models aids unnecessary use. Sub-models are selected based on the user requirements and the application. Only a *3DCDM Root Model* can be used in each implementation of the 3DCDM model.

The logical model of the 3DCDM is utilised as a base to develop the physical model of the 3DCDM. The next chapter describes the fourth step of 3D cadastral data-modelling development cycle in this thesis.

CHAPTER 8 – PHYSICAL DATA MODELLING OF THE 3DCDM

8 PHYSICAL DATA MODELLING OF 3DCDM

8.1 INTRODUCTION

The aim of this chapter is to convert the logical data model of the 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 as the fourth step of 3D cadastral data-modelling development cycle in this chapter. 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.

All XML schemas are presented in Appendix D.

8.2 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).

8.3 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 8.1.

Table 8.1: 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 8.2.

Table 8.2: 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

8.4 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.

8.4.1 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 8.3.

Table 8.3: 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:

UrbanCadastralModel, urbanCadastralModelType

```
<!-- ================================================================================ -->
<xs:element name="UrabnCadastralModel" type="urabnCadastralModelType"
substitutionGroup="gml:AbstractFeatureCollection"/>
<!-- ================================================================================ -->
  <xs:complexType name="urabnCadastralModelType">
    <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>
<!-- ================================================================================ -->
```

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.

applicationType, Application

```
<!-- ================================================================================ -->
  <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>
<!-- ===================================================================================== -->
```

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*.

metricUnitType, MetricUnit

```
<!-- ===================================================================================== -->
   <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>
<!-- ===================================================================================== -->
```

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.*

physicalModelType, urbanModelType, physicalObjectMemberType, _UrbanObject, AbstractUrbanObjectType

```
<!-- ===================================================================================== -->
<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>
```

```xml
            <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 *UrbanModel* of the 3DCDM, which is the root element of the 3DCDM's physical hierarcy. *physicalObjectMember* connects the class *UrbanModel* to the abstract class *_UrbanObject* using *physicalObjectMemberType*. *AbstractUrbanObjectType* describes the abstract superclass of urban objects.

_PhysicalPropertyObject, AbstractPhysicalPropertyObjectType, consistsOfPPOType, 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>
  <!-- ========================================================================= -->
```

_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 *AbstractPhysicalPropertyObjectType*. *_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*.

legalModelType, cadastralModelype, legalObjectMemberType, _CadastralObject, AbstractCadastralObjectType

```
  <!-- ========================================================================= -->
    <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>
  <!-- ========================================================================= -->
```

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 hierarcy. *legalObjectMember* connects the class *CadastralModel* to the abstract class *_CadastralObject* using *legalObjectMemberType*. *AbstractCadastralObjectType* describes the abstract superclass of cadastral objects.

8.4.2 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 8.4:

Table 8.4: 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:

LegalPropertyObject, LPOType

```
<!-- ================================================================================ -->
<xs:element name="LegalPropertyObject" type="LPOType" substitutionGroup="root:_CadastralObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="LPOType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of legal property
      objects.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
```

```
        <xs:documentation> </xs:documentation>
      </xs:annotation>
      <xs:element name="address" type="addressType" minOccurs="0"/>
      <xs:element name="proprietor" type="proprietorType" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element name="legalDocument" type="legalDocumentType" minOccurs="0" maxOccurs="1"/>
      <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
      maxOccurs="1"/>
      <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
      maxOccurs="1"/>
      <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
      <xs:element name="boundedBy" type="BoundarySurfaceType" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element name="ppo" type="root:AbstractPhysicalPropertyObjectType" minOccurs="0"
      maxOccurs="unbounded"/>
      <xs:element name="consistsOfLPO" type="consistsOfLPOType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute name="name" type="xs:string" use="optional"/>
    <xs:attribute name="lpoFormat" type="lpoFormatType" use="required"/>
    <xs:attribute name="lpoUnit" type="lpoUnitType" use="required"/>
    <xs:attribute name="rrr" type="rrrType" use="required"/>
    <xs:attribute name="lpoClass" type="lpoClassType" use="required"/>
    <xs:attribute name="area" type="xs:double" use="optional"/>
    <xs:attribute name="volume" type="xs:double" use="optional"/>
    <xs:attribute name="lotEntitlement" type="xs:string" use="optional"/>
    <xs:attribute name="lotLiability" type="xs:string" use="optional"/>
    <xs:attribute name="landUse" type="landUseType" use="optional"/>
    <xs:attribute name="lpoState" type="lpoStateType" use="required"/>
    <xs:attribute name="ppoRef" type="xs:IDREF" use="optional"/>
   </xs:extension>
  </xs:complexContent>
 </xs:complexType>
<!-- ======================================================================================= -->
```

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 *LegalDocument* using *legalDocumentType*. *MultiCurvePropertyType* and *MultiSurfacePropertyType* represent 2D *LegalPropertyObject*. *SolidPropertyType* and *MultiSurfacePropertyType* 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 *LegalPropertyObject* are *name*, *lpoFormat*, *lpoUnit*, *rrr*, *lpoClass*, *area*, *volume*, *lotEntitlement*, *lotLiability*, *landUse*, *lpoState*, and *ppoRef*.

consistsOfLPOType, proprietorType

```
<!-- ===================================================================================== -->
  <xs:complexType name="consistsOfLPOType">
    <xs:annotation>
      <xs:documentation>Type describing the aggregation of legal property objects.</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="LegalPropertyObject"/>
    </xs:sequence>
  </xs:complexType>
<!-- ===================================================================================== -->
  <xs:complexType name="proprietorType">
    <xs:annotation>
      <xs:documentation>Type describing the owner.</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="ownr:InterestHolder"/>
    </xs:sequence>
  </xs:complexType>
<!-- ===================================================================================== -->
```

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*.

legalDocumentType, Title, titleType

```
<!-- ===================================================================================== -->
  <xs:complexType name="legalDocumentType">
    <xs:sequence>
      <xs:element ref="Title"/>
    </xs:sequence>
  </xs:complexType>
<!-- ===================================================================================== -->
  <xs:element name="Title" type="titleType"/>
<!-- ===================================================================================== -->
  <xs:complexType name="titleType">
    <xs:annotation>
      <xs:documentation>Type describing the title element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="locatedAs" type="planDescType" minOccurs="0"/>
      <xs:element name="refersTo" type="parentType" minOccurs="0"/>
      <xs:element name="loan" type="loanType" minOccurs="0"/>
      <xs:element name="restrictedBy" type="encumbranceType" minOccurs="0"/>
      <xs:element name="managedBy" type="managementType" minOccurs="0"/>
      <xs:element name="property" type="LPOType" minOccurs="0" maxOccurs="1"/>
    </xs:sequence>
    <xs:attribute name="volume" type="nonBlankString" use="required"/>
    <xs:attribute name="folio" type="nonBlankString" use="required"/>
    <xs:attribute name="securityNo" type="xs:string" use="optional"/>
    <xs:attribute name="producedDate" type="xs:date" use="optional"/>
    <xs:attribute name="producedTime" type="xs:time" use="optional"/>
    <xs:attribute name="noOfParentTitle" type="xs:integer" use="optional"/>
  </xs:complexType>
<!-- ===================================================================================== -->
```

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.*

planDescType, landDescriptionType, parentType, parentTitleType

```
<!-- ================================================================================ -->
  <xs:complexType name="planDescType">
    <xs:sequence>
      <xs:element name="LandDescription" type="landDescriptionType"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="landDescriptionType">
    <xs:annotation>
      <xs:documentation>Type describing the land description of the title.</xs:documentation>
    </xs:annotation>
    <xs:attribute name="lotNo" type="nonBlankString" use="required"/>
    <xs:attribute name="planNo" type="nonBlankString" use="required"/>
    <xs:attribute name="plan" type="planType" use="required"/>
    <xs:attribute name="desc" type="xs:string" use="optional"/>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="parentType">
    <xs:sequence>
      <xs:element name="ParentTitle" type="parentTitleType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="parentTitleType">
    <xs:annotation>
      <xs:documentation>Type describing the parent title element.</xs:documentation>
    </xs:annotation>
    <xs:attribute name="volume" type="nonBlankString" use="required"/>
    <xs:attribute name="folio" type="nonBlankString" use="required"/>
  </xs:complexType>
<!-- ================================================================================ -->
```

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*.

loanType, mortgageType, encumbranceType, caveatType, managementType, ownersCorportationsType

```
<!-- ================================================================================ -->
  <xs:complexType name="loanType">
    <xs:sequence>
      <xs:element name="Mortgage" type="mortgageType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="mortgageType">
    <xs:annotation>
      <xs:documentation>Type describing the mortgage element.</xs:documentation>
    </xs:annotation>
    <xs:attribute name="mortgageRef" type="nonBlankString" use="required"/>
    <xs:attribute name="mortgageType" type="xs:date" use="required"/>
```

```
            <xs:attribute name="bankName" type="nonBlankString" use="required"/>
        </xs:complexType>
<!-- =========================================================================== -->
        <xs:complexType name="encumbranceType">
            <xs:sequence>
                <xs:element name="Caveat" type="caveatType" minOccurs="0" maxOccurs="unbounded"/>
            </xs:sequence>
        </xs:complexType>
<!-- =========================================================================== -->
        <xs:complexType name="caveatType">
            <xs:annotation>
                <xs:documentation>Type describing the caveat element.</xs:documentation>
            </xs:annotation>
            <xs:attribute name="caveatRef" type="nonBlankString" use="required"/>
            <xs:attribute name="caveatDate" type="xs:date" use="required"/>
            <xs:attribute name="caveator" type="nonBlankString" use="required"/>
        </xs:complexType>
<!-- =========================================================================== -->
        <xs:complexType name="managementType">
            <xs:sequence>
                <xs:element name="OwnersCorporations" type="ownersCorporationsType" minOccurs="0"
                maxOccurs="unbounded"/>
            </xs:sequence>
        </xs:complexType>
<!-- =========================================================================== -->
        <xs:complexType name="ownersCorporationsType">
            <xs:annotation>
                <xs:documentation>Type describing the owners corporations element.</xs:documentation>
            </xs:annotation>
            <xs:attribute name="ownersCorpPlanNo" type="xs:string" use="required"/>
        </xs:complexType>
<!-- =========================================================================== -->
```

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*.

BoundarySurfaceType, _BoundaryType, AbstractBoundarySurfaceType

```
<!-- =========================================================================== -->
        <xs:complexType name="BoundarySurfaceType">
            <xs:annotation>
                <xs:documentation>Type describing boundary surface </xs:documentation>
            </xs:annotation>
            <xs:sequence minOccurs="0">
                <xs:element ref="_BoundaryType"/>
            </xs:sequence>
        </xs:complexType>
<!-- =========================================================================== -->
        <xs:element name="_BoundaryType" type="AbstractBoundaryType" abstract="true"/>
<!-- =========================================================================== -->
        <xs:complexType name="AbstractBoundaryType" abstract="true">
            <xs:annotation>
                <xs:documentation>Type describing _BoundaryType</xs:documentation>
            </xs:annotation>
            <xs:sequence>
                <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
                maxOccurs="1"/>
            </xs:sequence>
```

```
        <xs:attribute name="boundary" type="boundaryType" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- ==================================================================================== -->
```

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*.

VirtualSurface, VirtualSurfaceType, WallSurface, WallSurfaceType, FloorSurface, FloorSurfaceType, CeilingSurface, CeilingSurfaceType

```
<!-- ==================================================================================== -->
<xs:element name="VirtualSurface" type=" VirtualSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ==================================================================================== -->
    <xs:complexType name=" VirtualSurfaceType">
        <xs:complexContent>
            <xs:extension base="AbstractBoundaryType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ==================================================================================== -->
<xs:element name="WallSurface" type="WallSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ==================================================================================== -->
    <xs:complexType name="WallSurfaceType">
        <xs:complexContent>
            <xs:extension base="AbstractBoundaryType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ==================================================================================== -->
    <xs:element name="FloorSurface" type="FloorSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ==================================================================================== -->
    <xs:complexType name="FloorSurfaceType">
        <xs:complexContent>
            <xs:extension base="AbstractBoundaryType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ==================================================================================== -->
    <xs:element name="CeilingSurface" type="CeilingSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ==================================================================================== -->
    <xs:complexType name="CeilingSurfaceType">
        <xs:complexContent>
            <xs:extension base="AbstractBoundaryType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ==================================================================================== -->
```

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 *CeilingSurfaceType* respectively.

RoofSurface, RoofSurfaceType, SlabSurface, SlabSurfaceType, SuspectedCeilingSurface, SuspectedCeilingSurfaceType, FloorJoistsSurface, FloorJoistsSurfaceType

```xml
<!-- ======================================================================================== -->
<xs:element name="RoofSurface" type="RoofSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ======================================================================================== -->
  <xs:complexType name="RoofSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================================== -->
  <xs:element name="SlabSurface" type="SlabSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ======================================================================================== -->
  <xs:complexType name="SlabSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================================== -->
  <xs:element name="SuspendedCeilingSurface" type="SuspendedCeilingSurfaceType"
  substitutionGroup="_BoundaryType"/>
<!-- ======================================================================================== -->
  <xs:complexType name="SuspendedCeilingSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================================== -->
  <xs:element name="FloorJoistsSurface" type="FloorJoistsSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ======================================================================================== -->
  <xs:complexType name="FloorJoistsSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================================== -->
```

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 *FloorJoistsSurfaceType* respectively.

8.4.3 XML SCHEMA FOR 3DCDM INTERSTHOLDER 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 8.5.

Table 8.5: 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:

InterestHolder, interestHolderType

```
<!-- ====================================================================== -->
  <xs:element name="InterestHolder" type="interestHolderType" substitutionGroup="root:_CadastralObject"/>
<!-- ====================================================================== -->
  <xs:complexType name="interestHolderType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of proprietors.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation>  </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="legalDocument" type="legalDocumentType" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="property" type="propertyType" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="pName" type="xs:string" use="optional"/>
        <xs:attribute name="share" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="type" type="ownerType" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ====================================================================== -->
```

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

legalDocumentType, propertyType

```
<!-- ====================================================================== -->
  <xs:complexType name="legalDocumentType">
    <xs:annotation>
      <xs:documentation>Type describing the title element.</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="lpo:Title"/>
    </xs:sequence>
  </xs:complexType>
<!-- ====================================================================== -->
```

```
    <xs:complexType name="propertyType">
        <xs:annotation>
            <xs:documentation>Type describing Legal Property Object.</xs:documentation>
        </xs:annotation>
        <xs:sequence minOccurs="0">
            <xs:element ref="lpo:LegalPropertyObject"/>
        </xs:sequence>
    </xs:complexType>
<!-- ========================================================================= -->
```

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*.

addressType, geocodedAddressType, addressPointType

```
<!-- ========================================================================= -->
    <xs:complexType name="addressType">
        <xs:sequence>
            <xs:element name="Address" type="addreType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ========================================================================= -->
    <xs:complexType name="addreType">
        <xs:annotation>
            <xs:documentation>Type describing the address element.</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
        <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
        <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
        <xs:attribute name="streetName" type="xs:string" use="optional"/>
        <xs:attribute name="streetType" type="xs:string" use="optional"/>
        <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
        <xs:attribute name="Suburb" type="xs:string" use="optional"/>
        <xs:attribute name="city" type="xs:string" use="optional"/>
        <xs:attribute name="state" type="xs:string" use="optional"/>
        <xs:attribute name="postCode" type="xs:string" use="optional"/>
        <xs:attribute name="country" type="xs:string" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- ========================================================================= -->
    <xs:complexType name="geocodedAddressType">
        <xs:sequence>
            <xs:element name="AddressPoint" type="addressPointType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ========================================================================= -->
    <xs:complexType name="addressPointType">
        <xs:annotation>
            <xs:documentation>Type describing the geocoded address element.</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="referencePoint" type="gml:PointPropertyType"/>
        </xs:sequence>
        <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
    </xs:complexType>
<!-- ========================================================================= -->
```

addressType describes the elements, attributes, and associations of the class *Address* using appropriate attributes. A geocoded address is described by *geocodedAddressType* and *addressPointType*.

8.4.4 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 8.6.

Table 8.6: 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:

Survey, surveyType

```
<!-- ============================================================================== -->
  <xs:element name="Survey" type="surveyType" substitutionGroup="root:_CadastralObject"/>
<!-- ============================================================================== -->
  <xs:complexType name="surveyType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of surveying
      element.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation/>
          </xs:annotation>
          <xs:element name="surveyedBy" type="surveyedByType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="initialisation" type="initialisationType" minOccurs="0"/>
          <xs:element name="observation" type="observationType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="jurisdiction" type="xs:string" use="optional"/>
        <xs:attribute name="legislation" type="xs:string" use="optional"/>
        <xs:attribute name="purposeofSurvey" type="xs:string" use="optional"/>
        <xs:attribute name="surveyDate" type="xs:date" use="optional"/>
        <xs:attribute name="surveyFormat" type="surFormatType" use="optional"/>
        <xs:attribute name="method" type="surMethod" use="optional"/>
```

```
            <xs:attribute name="fieldNoteRef" type="xs:string" use="optional"/>
            <xs:attribute name="desc" type="xs:string" use="optional"/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>
<!-- ======================================================================== -->
```

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

surveyedByType, surveyorType

```
<!-- ======================================================================== -->
   <xs:complexType name="surveyedByType">
      <xs:annotation>
         <xs:documentation>Type describing surveyor information</xs:documentation>
      </xs:annotation>
      <xs:sequence>
         <xs:element name="surveyor" type="surveyorType" minOccurs="0" maxOccurs="1"/>
      </xs:sequence>
   </xs:complexType>
<!-- ======================================================================== -->
   <xs:complexType name="surveyorType">
      <xs:annotation>
         <xs:documentation>Type describing surveyor</xs:documentation>
      </xs:annotation>
      <xs:attribute name="name" type="xs:string" use="optional"/>
      <xs:attribute name="regNumber" type="xs:string" use="optional"/>
      <xs:attribute name="surveyorFirm" type="xs:string" use="optional"/>
   </xs:complexType>
<!-- ======================================================================== -->
```

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

initialisationType, setupInstrumentType, referencePointType, setupPointType

```
<!-- ======================================================================== -->
   <xs:complexType name="initialisationType">
      <xs:annotation>
         <xs:documentation>Comment describing initialisationType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
         <xs:element name="SetupInstrument" type="setupInstrumentType" minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
   </xs:complexType>
<!-- ======================================================================== -->
   <xs:complexType name="setupInstrumentType">
      <xs:annotation>
         <xs:documentation>Comment describing setupInstrumentType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
         <xs:element name="referencePoint" type="referencePointType"/>
      </xs:sequence>
      <xs:attribute name="setupID" type="xs:ID" use="required"/>
      <xs:attribute name="stationName" type="nonBlankString" use="required"/>
      <xs:attribute name="instrumentHeight" type="xs:double" use="required"/>
   </xs:complexType>
<!-- ======================================================================== -->
   <xs:complexType name="referencePointType">
```

```
        <xs:annotation>
            <xs:documentation>Comment describing referencePointType</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="SetupPoint" type="setupPointType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ========================================================================= -->
    <xs:complexType name="setupPointType">
        <xs:annotation>
            <xs:documentation>Comment describing setupPointType</xs:documentation>
        </xs:annotation>
        <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
    </xs:complexType>
<!-- ========================================================================= -->
```

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

observationType, observationGroupType

```
<!-- ========================================================================= -->
    <xs:complexType name="observationType">
        <xs:annotation>
            <xs:documentation>Comment describing observationType</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="ObservationGroup" type="observationGroupType" minOccurs="0"/>
        </xs:sequence>
    </xs:complexType>
<!-- ========================================================================= -->
    <xs:complexType name="observationGroupType">
        <xs:annotation>
            <xs:documentation>Comment describing observationGroupType</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:choice maxOccurs="unbounded">
                <xs:element name="reducedLineObservation" type="reducedLineObservationType" minOccurs="0"/>
                <xs:element name="reducedArcObservation" type="reducedArcObservationType" minOccurs="0"/>
            </xs:choice>
        </xs:sequence>
        <xs:attribute name="id" type="xs:ID" use="required"/>
    </xs:complexType>
<!-- ========================================================================= -->
```

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

reducedLineObservationType, redHorizontalLineObservationType

```
<!-- ========================================================================= -->
    <xs:complexType name="reducedLineObservationType">
        <xs:annotation>
            <xs:documentation>Comment describing reducedLineObservationType</xs:documentation>
        </xs:annotation>
        <xs:sequence>
```

```
        <xs:element name="RedHorizontalLineObservation" type="redHorizontalLineObservationType"/>
      </xs:sequence>
    </xs:complexType>
  <!-- ============================================================================ -->
    <xs:complexType name="redHorizontalLineObservationType">
      <xs:annotation>
        <xs:documentation>Comment describing redHorizontalLineObservation</xs:documentation>
      </xs:annotation>
      <xs:attribute name="name" type="xs:ID" use="required"/>
      <xs:attribute name="desc" type="nonBlankString" use="optional"/>
      <xs:attribute name="purpose" type="purposeType" use="required"/>
      <xs:attribute name="setupID" type="xs:IDREF" use="required"/>
      <xs:attribute name="targetSetupID" type="xs:IDREF" use="required"/>
      <xs:attribute name="azimuth" type="xs:double" use="required"/>
      <xs:attribute name="horizDistance" type="xs:double" use="required"/>
      <xs:attribute name="azimuthAccuracy" type="xs:double" use="optional"/>
      <xs:attribute name="distanceAccuracy" type="xs:double" use="optional"/>
      <xs:attribute name="fieldNoteRef" type="xs:string" use="optional"/>
    </xs:complexType>
  <!-- ============================================================================ -->
```

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

reducedArcObservationType, redHorizontalArcObservationType

```
  <!-- ============================================================================ -->
    <xs:complexType name="reducedArcObservationType">
      <xs:annotation>
        <xs:documentation>Comment describing reducedArcObservationType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
        <xs:element name="RedHorizontalArcObservation" type="redHorizontalArcObservationType"/>
      </xs:sequence>
    </xs:complexType>
  <!-- ============================================================================ -->
    <xs:complexType name="redHorizontalArcObservationType">
      <xs:annotation>
        <xs:documentation>Comment describing redHorizontalArcObservationType</xs:documentation>
      </xs:annotation>
      <xs:attribute name="name" type="xs:ID" use="required"/>
      <xs:attribute name="desc" type="xs:string" use="optional"/>
      <xs:attribute name="purpose" type="purposeType" use="required"/>
      <xs:attribute name="setupID" type="xs:IDREF" use="required"/>
      <xs:attribute name="targetSetupID" type="xs:IDREF" use="required"/>
      <xs:attribute name="chordAzimuth" type="xs:double" use="required"/>
      <xs:attribute name="radius" type="xs:double" use="required"/>
      <xs:attribute name="length" type="xs:double" use="required"/>
      <xs:attribute name="rot" type="clockwise" use="required"/>
      <xs:attribute name="arcAzimuthAccuracy" type="xs:double" use="optional"/>
      <xs:attribute name="arcLengthAccuracy" type="xs:double" use="optional"/>
      <xs:attribute name="fieldNoteRef" type="xs:string" use="optional"/>
    </xs:complexType>
  <!-- ============================================================================ -->
```

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

8.4.5 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 8.7.

Table 8.7: 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:

CadastralPoints, cadastralPointsType

```
<!-- ================================================================================ -->
  <xs:element name="CadastralPoints" type="cadastralPointsType" substitutionGroup="root:_CadastralObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="cadastralPointsType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of cadastral
      points.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation/>
          </xs:annotation>
          <xs:element name="referencePointMember" type="referencePointMemberType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="name" type="xs:string" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
```

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

referencePointMemberType, cadastralPointType

```
<!-- ===================================================================== -->
  <xs:complexType name="referencePointMemberType">
    <xs:annotation>
      <xs:documentation>Comment describing referencePointMemberType</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="CadastralPoint" type="cadastralPointType" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- ===================================================================== -->
  <xs:complexType name="cadastralPointType">
    <xs:annotation>
      <xs:documentation>Comment describing cadastralPointType</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="referencePoint" type="gml:PointPropertyType" minOccurs="1"/>
    </xs:sequence>
    <xs:attribute name="name" type="xs:ID" use="required"/>
    <xs:attribute name="state" type="pointStateType" use="required"/>
    <xs:attribute name="monument" type="monumentType" use="optional"/>
  </xs:complexType>
<!-- ===================================================================== -->
```

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

8.4.6 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 8.8.

Table 8.8: 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:

Building, BuildingType

```
<!-- =========================================================================== -->
  <xs:element name="Building" type="BuildingType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- =========================================================================== -->
  <xs:complexType name="BuildingType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of buildings.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="terrainIntersection" type="gml:MultiCurvePropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="consistsOfBuildingPart" type="BuildingPartPropertyType" minOccurs="0"
          maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="landUse" type="landUseType" use="optional"/>
        <xs:attribute name="constructionYear" type="xs:gYear" use="optional"/>
        <xs:attribute name="buildingHeight" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="noOfStoreysAboveGround" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="noOfStoreysBelowGround" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="buildingHeightAboveGround" type="xs:double" use="optional"/>
        <xs:attribute name="buildingHeightBelowGround" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- =========================================================================== -->
```

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

_BuildingPart, AbstractBuildingPartType

```
<!-- =========================================================================== -->
  <xs:element name="_BuildingPart" type="AbstractBuildingPartType" abstract="true"
  substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- =========================================================================== -->
  <xs:complexType name="AbstractBuildingPartType" abstract="true">
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:element name="consistsOfStructuralComponent" type="StructuralComponentPropertyType"
          minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="consistsOfSpace" type="SpacePropertyType" minOccurs="0"/>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
        </xs:sequence>
        <xs:attribute name="area" type="xs:double" use="optional"/>
        <xs:attribute name="volume" type="xs:double" use="optional"/>
```

```
            <xs:attribute name="type" type="xs:string" use="optional"/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>
<!-- =============================================================================== -->
```

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

SpacePropertyType, Space, SpaceType

```
<!-- =============================================================================== -->
   <xs:complexType name="SpacePropertyType">
      <xs:annotation>
         <xs:documentation>Comment describing SpacePropertyType</xs:documentation>
      </xs:annotation>
      <xs:sequence minOccurs="0">
         <xs:element ref="Space"/>
      </xs:sequence>
   </xs:complexType>
<!-- =============================================================================== -->
   <xs:element name="Space" type="SpaceType"/>
<!-- =============================================================================== -->
   <xs:complexType name="SpaceType">
      <xs:annotation>
         <xs:documentation>Comment describing SpacePropertType.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
         <xs:extension base="root:AbstractPhysicalPropertyObjectType">
            <xs:sequence>
               <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
               <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
               maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute name="area" type="xs:double" use="optional"/>
            <xs:attribute name="volume" type="xs:double" use="optional"/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>
<!-- =============================================================================== -->
```

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

StructuralComponentPropertyType, _StructuralComponent, AbstractStructuralComponentType

```
<!-- =============================================================================== -->
   <xs:complexType name="StructuralComponentPropertyType">
      <xs:annotation>
         <xs:documentation>Comment describing StructurePropertyType</xs:documentation>
      </xs:annotation>
      <xs:sequence minOccurs="0">
         <xs:element ref="_StructuralComponent"/>
      </xs:sequence>
   </xs:complexType>
<!-- =============================================================================== -->
   <xs:element name="_StructuralComponent" type="AbstractStructuralComponentType" abstract="true"
   substitutionGroup="root:_PhysicalPropertyObject"/>
```

```
<!-- ====================================================================== -->
<xs:complexType name="AbstractStructuralComponentType" abstract="true">
   <xs:annotation>
      <xs:documentation>Comment describing AbstractStructuralComponentType</xs:documentation>
   </xs:annotation>
   <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
         <xs:sequence>
            <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
            <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
            maxOccurs="1"/>
         </xs:sequence>
         <xs:attribute name="width" type="xs:double" use="optional"/>
         <xs:attribute name="length" type="xs:double" use="optional"/>
         <xs:attribute name="area" type="xs:double" use="optional"/>
         <xs:attribute name="volume" type="xs:double" use="optional"/>
      </xs:extension>
   </xs:complexContent>
</xs:complexType>
<!-- ====================================================================== -->
```

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*.

Wall, WallType, Floor, FloorType, Ceiling, CeilingType

```
<!-- ====================================================================== -->
<xs:element name="Wall" type="WallType" substitutionGroup="_StructuralComponent"/>
<!-- ====================================================================== -->
<xs:complexType name="WallType">
   <xs:annotation>
      <xs:documentation>Comment describing WallType</xs:documentation>
   </xs:annotation>
   <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
   </xs:complexContent>
</xs:complexType>
<!-- ====================================================================== -->
<xs:element name="Floor" type="FloorType" substitutionGroup="_StructuralComponent"/>
<!-- ====================================================================== -->
<xs:complexType name="FloorType">
   <xs:annotation>
      <xs:documentation>Comment describing FloorType</xs:documentation>
   </xs:annotation>
   <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
   </xs:complexContent>
</xs:complexType>
<!-- ====================================================================== -->
<xs:element name="Ceiling" type="CeilingType" substitutionGroup="_StructuralComponent"/>
<!-- ====================================================================== -->
<xs:complexType name="CeilingType">
   <xs:annotation>
      <xs:documentation>Comment describing CeilingType</xs:documentation>
   </xs:annotation>
   <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
   </xs:complexContent>
</xs:complexType>
<!-- ====================================================================== -->
```

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

Structure, StructureType, Door, DoorType, Window, WindowType

```
<!-- ========================================================================= -->
  <xs:element name="Structure" type="StructureType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================= -->
  <xs:complexType name="StructureType">
    <xs:annotation>
      <xs:documentation>Comment describing StructureType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================= -->
  <xs:element name="Door" type="DoorType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================= -->
  <xs:complexType name="DoorType">
    <xs:annotation>
      <xs:documentation>Comment describing DoorType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================= -->
  <xs:element name="Window" type="WindowType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================= -->
  <xs:complexType name="WindowType">
    <xs:annotation>
      <xs:documentation>Comment describing WindowType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================= -->
```

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

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

```
<!-- ========================================================================= -->
  <xs:element name="Unit" type="UnitType" substitutionGroup="_BuildingPart"/>
<!-- ========================================================================= -->
  <xs:complexType name="UnitType">
    <xs:annotation>
      <xs:documentation>Comment describing UnitType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractBuildingPartType">
        <xs:attribute name="unitNo" type="xs:string" use="optional"/>
        <xs:attribute name="storeyNo" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="landUse" type="landUseType" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================= -->
  <xs:element name="CarPark" type="CarParkType" substitutionGroup="_BuildingPart"/>
```

```xml
<!-- ======================================================================== -->
  <xs:complexType name="CarParkType">
    <xs:annotation>
      <xs:documentation>Comment describing CarParkType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractBuildingPartType">
        <xs:attribute name="carparkNo" type="xs:string" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================== -->
  <xs:element name="ServiceRoom" type="ServiceRoomType" substitutionGroup="_BuildingPart"/>
<!-- ======================================================================== -->
  <xs:complexType name="ServiceRoomType">
    <xs:annotation>
      <xs:documentation>Comment describing ServiceRoomType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractBuildingPartType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================== -->
  <xs:element name="StorageRoom" type="StorageRoomType" substitutionGroup="_BuildingPart"/>
<!-- ======================================================================== -->
  <xs:complexType name="StorageRoomType">
    <xs:annotation>
      <xs:documentation>Comment describing StorageRoomType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractBuildingPartType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================== -->
```

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

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

```xml
<!-- ======================================================================== -->
  <xs:element name="Pathway" type="PathwayType" substitutionGroup="_BuildingPart"/>
<!-- ======================================================================== -->
  <xs:complexType name="PathwayType">
    <xs:annotation>
      <xs:documentation>Comment describing PathwayType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractBuildingPartType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================== -->
  <xs:element name="Balcony" type="BalconyType" substitutionGroup="_BuildingPart"/>
<!-- ======================================================================== -->
  <xs:complexType name="BalconyType">
    <xs:annotation>
      <xs:documentation>Comment describing BalconyType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractBuildingPartType">
        <xs:attribute name="unitNo" type="xs:string" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ======================================================================== -->
  <xs:element name="Roof" type="RoofType" substitutionGroup="_BuildingPart"/>
<!-- ======================================================================== -->
```

```xml
    <xs:complexType name="RoofType">
        <xs:annotation>
            <xs:documentation>Comment describing RoofType</xs:documentation>
        </xs:annotation>
        <xs:complexContent>
            <xs:extension base="AbstractBuildingPartType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================== -->
    <xs:element name="BuildingPart" type="BuildingPartType" substitutionGroup="_BuildingPart"/>
<!-- ====================================================================== -->
    <xs:complexType name="BuildingPartType">
        <xs:annotation>
            <xs:documentation>Comment describing BuildingPartType</xs:documentation>
        </xs:annotation>
        <xs:complexContent>
            <xs:extension base="AbstractBuildingPartType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================== -->
```

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

8.4.7 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 8.9.

Table 8.9: 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

Basic elements of this model are presented below:

Land, landType

```
<!-- ================================================================================ -->
  <xs:element name="Land" type="landType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="landType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of land.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
        </xs:sequence>
        <xs:attribute name="landUse" type="xs:string" use="optional"/>
        <xs:attribute name="area" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
```

landType describes the elements, attributes and associations of the class *Land* using attributes *landuse* and *area*.

8.4.8 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 8.10.

Table 8.10: 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

Basic elements of this model are presented below:

Tunnel, TunnelType

```
<!-- ================================================================================ -->
  <xs:element name="Tunnel" type="TunnelType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="TunnelType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of tunnels.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="terrainIntersection" type="gml:MultiCurvePropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="consistsOfStructuralComponent" type="StructuralComponentPropertyType"
          minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="consistsOfSpace" type="SpacePropertyType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="usage" type="xs:string" use="optional"/>
        <xs:attribute name="constructionYear" type="xs:gYear" use="optional"/>
        <xs:attribute name="heightBelowGround" type="xs:double" use="optional"/>
        <xs:attribute name="length" type="xs:double" use="optional"/>
        <xs:attribute name="width" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
```

tunnelType describes the elements, attributes and associations of the class *Tunnel* using attributes *usage*, *constructionYear*, *heightBelowGround*, *length*, and *width*.

SpacePropertyType, Space, SpaceType

```
<!-- ================================================================================ -->
  <xs:complexType name="SpacePropertyType">
    <xs:sequence minOccurs="0">
      <xs:element ref="Space"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="Space" type="SpaceType"/>
<!-- ================================================================================ -->
  <xs:complexType name="SpaceType">
    <xs:annotation>
      <xs:documentation>Type describing the space element of the tunnel.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
        </xs:sequence>
        <xs:attribute name="area" type="xs:double" use="optional"/>
        <xs:attribute name="volume" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
```

```
    </xs:complexType>
<!-- ========================================================================== -->
```

Class *Tunnel* consists of space that is described by *SpacePropertyType*. *SpaceType* describes the class *Space* using attributes *area* and *volume*. Each *Space* is represented by *SolidPropertyType* and *MultiSurfacePropertyType*.

StructuralComponentPropertyType, _StructuralComponent, AbstractStructuralComponentType

```
<!-- ========================================================================== -->
    <xs:complexType name="StructuralComponentPropertyType">
        <xs:sequence minOccurs="0">
            <xs:element ref="_StructuralComponent"/>
        </xs:sequence>
    </xs:complexType>
<!-- ========================================================================== -->
    <xs:element name="_StructuralComponent" type="AbstractStructuralComponentType" abstract="true"
    substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ========================================================================== -->
    <xs:complexType name="AbstractStructuralComponentType" abstract="true">
        <xs:annotation>
            <xs:documentation>Type describing the structural component of the tunnel.</xs:documentation>
        </xs:annotation>
        <xs:complexContent>
            <xs:extension base="root:AbstractPhysicalPropertyObjectType">
                <xs:sequence>
                    <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
                    <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
                    maxOccurs="1"/>
                </xs:sequence>
                <xs:attribute name="width" type="xs:double" use="optional"/>
                <xs:attribute name="length" type="xs:double" use="optional"/>
                <xs:attribute name="area" type="xs:double" use="optional"/>
                <xs:attribute name="volume" type="xs:double" use="optional"/>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
<!-- ========================================================================== -->
```

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

Wall, WallType, Floor, FloorType, Ceiling, CeilingType, Strcture, StructureType

```
<!-- ========================================================================== -->
    <xs:element name="Wall" type="WallType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================== -->
    <xs:complexType name="WallType">
        <xs:annotation>
            <xs:documentation>Type describing the wall element of the tunnel.</xs:documentation>
        </xs:annotation>
        <xs:complexContent>
            <xs:extension base="AbstractStructuralComponentType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ========================================================================== -->
    <xs:element name="Floor" type="FloorType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================== -->
    <xs:complexType name="FloorType">
```

```
    <xs:annotation>
      <xs:documentation>Type describing the floor element of the tunnel.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:element name="Ceiling" type="CeilingType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================== -->
  <xs:complexType name="CeilingType">
    <xs:annotation>
      <xs:documentation>Type describing the ceiling element of the tunnel.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:element name="Structure" type="StructureType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================== -->
  <xs:complexType name="StructureType">
    <xs:annotation>
      <xs:documentation>Type describing the any elements of the tunnel.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================== -->
```

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

8.4.9 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 8.11.

Table 8.11: 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

Basic elements of this model are presented below:

_UtilityNetwork, AbstractUtilityNetwork Type

```
<!-- ============================================================================== -->
   <xs:element name="_UtilityNetwork" type="AbstractUtilityNetworkType" abstract="true"
   substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ============================================================================== -->
   <xs:complexType name="AbstractUtilityNetworkType">
      <xs:annotation>
         <xs:documentation>Type describing the elements, attributes, and associations of any utility
         networks.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
         <xs:extension base="root:AbstractPhysicalPropertyObjectType">
            <xs:sequence>
               <xs:annotation>
                  <xs:documentation> </xs:documentation>
               </xs:annotation>
               <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
               <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
               maxOccurs="1"/>
               <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
               maxOccurs="1"/>
               <xs:element name="representedBySolid" type="gml:MultiSolidPropertyType" minOccurs="0"
               maxOccurs="1"/>
               <xs:element name="consistsOfNetworkComponent" type="NetworkComponentPropertyType" minOccurs="0"
               maxOccurs="unbounded"/>
            </xs:sequence>
            <xs:attribute name="networkLength" type="xs:double" use="optional"/>
            <xs:attribute name="constructionYear" type="xs:gYear" use="optional"/>
            <xs:attribute name="networkHeightBelowGround" type="xs:double" use="optional"/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>
<!-- ============================================================================== -->
```

AbstractUtilityNetworkType describes the elements, attributes and associations of the abstract class *_UtilityNetwork* using attributes *networkLength*, *constructionYear*, and *networkHeightBelowGround*.

NetworkComponentPropertyType, NetworkComponent, NetworkComponentType

```
<!-- ============================================================================== -->
   <xs:complexType name="NetworkComponentPropertyType">
      <xs:sequence minOccurs="0">
         <xs:element ref="NetworkComponent"/>
      </xs:sequence>
   </xs:complexType>
<!-- ============================================================================== -->
   <xs:element name="NetworkComponent" type="NetworkComponentType"
substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ============================================================================== -->
   <xs:complexType name="NetworkComponentType">
```

```
      <xs:annotation>
        <xs:documentation>Type describing the elements, attributes, and associations of network
        components.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
        <xs:extension base="root:AbstractPhysicalPropertyObjectType">
          <xs:sequence>
            <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
            maxOccurs="1"/>
            <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
            maxOccurs="1"/>
            <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          </xs:sequence>
          <xs:attribute name="material" type="xs:string" use="optional"/>
          <xs:attribute name="width" type="xs:double" use="optional"/>
          <xs:attribute name="length" type="xs:double" use="optional"/>
          <xs:attribute name="area" type="xs:double" use="optional"/>
          <xs:attribute name="volume" type="xs:double" use="optional"/>
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
  <!-- ============================================================================ -->
```

Abstract class *_UtilityNetwork* consists of network components that is described by *NetworkComponentPropertyType*. *NetworkComponentType* describes the class *NetworkComponent* using attributes *material*, *width*, *length*, *area*, and *volume*. Each *Space* is represented by *representedByMultiCurve*, *representedByMultiSurface*, and *representedBySolid*.

WaterNetwork, WaterNetworkType

```
  <!-- ============================================================================ -->
    <xs:element name="WaterNetwork" type="WaterNetworkType" substitutionGroup="_UtilityNetwork"/>
  <!-- ============================================================================ -->
    <xs:complexType name="WaterNetworkType">
      <xs:annotation>
        <xs:documentation>Type describing the water network element.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
        <xs:extension base="AbstractUtilityNetworkType"/>
      </xs:complexContent>
    </xs:complexType>
  <!-- ============================================================================ -->
```

WaterNetworkType describes class *WaterNetwork* that is a subclass of the abstract class *_UtilityNetwork*.

TelecommunicationNetwork, TelecommunicationNetworkType

```
  <!-- ============================================================================ -->
    <xs:element name="TelecommunicationNetwork" type="TelecommunicationNetworkType"
    substitutionGroup="_UtilityNetwork"/>
  <!-- ============================================================================ -->
    <xs:complexType name="TelecommunicationNetworkType">
      <xs:annotation>
        <xs:documentation>Type describing the telecommunication network element.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
        <xs:extension base="AbstractUtilityNetworkType"/>
```

```
        </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================================== -->
```

TelecommunicationNetworkType describes the class *TelecommunicationNetwork*, which is a subclass of the abstract class *_UtilityNetwork*.

WasteNetwork, WasteNetworkType

```
<!-- ====================================================================================== -->
    <xs:complexType name="SpacePropertyType">
        <xs:sequence minOccurs="0">
            <xs:element ref="Space"/>
        </xs:sequence>
    </xs:complexType>
<!-- ====================================================================================== -->
    <xs:element name="Space" type="SpaceType"/>
<!-- ====================================================================================== -->
    <xs:complexType name="SpaceType">
        <xs:annotation>
            <xs:documentation>Type describing the space element of the tunnel.</xs:documentation>
        </xs:annotation>
        <xs:complexContent>
            <xs:extension base="root:AbstractPhysicalPropertyObjectType">
                <xs:sequence>
                    <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
                    <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
                    maxOccurs="1"/>
                </xs:sequence>
                <xs:attribute name="area" type="xs:double" use="optional"/>
                <xs:attribute name="volume" type="xs:double" use="optional"/>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================================== -->
```

WasteNetworkType describes the class *WasteNetwork*, which is a subclass of the abstract class *_UtilityNetwork*.

ElectricityNetwork, ElectricityNetworkType

```
<!-- ====================================================================================== -->
    <xs:element name="ElectricityNetwork" type="ElectricityNetworkType" substitutionGroup="_UtilityNetwork"/>
<!-- ====================================================================================== -->
    <xs:complexType name="ElectricityNetworkType">
        <xs:annotation>
            <xs:documentation>Type describing the electricity network element.</xs:documentation>
        </xs:annotation>
        <xs:complexContent>
            <xs:extension base="AbstractUtilityNetworkType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================================== -->
```

ElectricityNetworkType describes the class *ElectricityNetwork*, which is a subclass of the abstract class *_UtilityNetwork*.

8.4.10 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 PhysicalPropertyObject 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 8.12.

Table 8.12: 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

Basic elements of this model are presented below:

PhysicalPropertyObject, PPOType

```
<!-- ============================================================================= -->
  <xs:element name="PhysicalPropertyObject" type="PPOType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ============================================================================= -->
  <xs:complexType name="PPOType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of any physical property
      objects.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation>  </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiPoint" type="gml:MultiPointPropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:MultiSolidPropertyType" minOccurs="0"
          maxOccurs="1"/>
        </xs:sequence>
```

```
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
  <!-- ===================================================================================== -->
```

PPOType describes elements, attributes, and associations of class *PhysicalPropertyObject*. Each *PhysicalPropertyObject* is represented by *representedByMultiPoint*, *representedByMultiCurve*, *representedByMultiSurface*, and *representedBySolid*.

8.4.11 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 8.13.

Table 8.13: 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

Basic elements of this model are presented below:

Terrain, terrainType

```
  <!-- ===================================================================================== -->
    <xs:element name="Terrain" type="terrainType" substitutionGroup="root:_UrbanObject"/>
  <!-- ===================================================================================== -->
    <xs:complexType name="terrainType">
      <xs:annotation>
        <xs:documentation>Type describing the terrain element of the model.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
        <xs:extension base="root:AbstractUrbanObjectType">
          <xs:sequence>
            <xs:element name="terrainSource" type="terrainSourceType" maxOccurs="unbounded"/>
          </xs:sequence>
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
  <!-- ===================================================================================== -->
```

terrainType describes elements, attributes, and associations of the class *Terrain*.

_TerrainSource, AbstractTerrainSourceType, terrainSourceType

```
<!-- ========================================================================= -->
  <xs:element name="_TerrainSource" type="AbstractTerrainSourceType" abstract="true"
  substitutionGroup="root:_UrbanObject"/>
<!-- ========================================================================= -->
  <xs:complexType name="AbstractTerrainSourceType">
    <xs:annotation>
      <xs:documentation>Type describing the abstract superclass of terrain sorces. </xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractUrbanObjectType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================= -->
  <xs:complexType name="terrainSourceType">
    <xs:annotation>
      <xs:documentation>Comment describing terrainSourceType </xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="_TerrainSource"/>
    </xs:sequence>
  </xs:complexType>
<!-- ========================================================================= -->
```

AbstractTerrainSourceType describes elements, attributes, and associations of the abstract class *_TerrainSource*. *terrainSourceType* connects the class *Terrain* to the abstract class *_TerrainSource*.

TIN, tinType, tinSourceType

```
<!-- ========================================================================= -->
  <xs:element name="TIN" type="tinType" substitutionGroup="_TerrainSource"/>
<!-- ========================================================================= -->
  <xs:complexType name="tinType">
    <xs:annotation>
      <xs:documentation>Type describing the TIN element of the model.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractTerrainSourceType">
        <xs:sequence>
          <xs:element name="tinSource" type="tinSourceType"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================= -->
  <xs:complexType name="tinSourceType">
    <xs:sequence minOccurs="0">
      <xs:element ref="gml:TriangulatedSurface"/>
    </xs:sequence>
  </xs:complexType>
<!-- ========================================================================= -->
```

tinType describes elements, attributes, and associations of the class *TIN*. *tinSourceType* specifies that the class *TIN* is modelled using *TriangulatedSurface*.

DEM, demType

```
<!-- ====================================================================================== -->
   <xs:element name="DEM" type="demType" substitutionGroup="_TerrainSource"/>
<!-- ====================================================================================== -->
   <xs:complexType name="demType">
      <xs:annotation>
         <xs:documentation>Type describing the DEM element of the model. </xs:documentation>
      </xs:annotation>
      <xs:complexContent>
         <xs:extension base="AbstractTerrainSourceType">
            <xs:sequence>
               <xs:element name="demSource" type="gml:MultiPointPropertyType"/>
            </xs:sequence>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>
<!-- ====================================================================================== -->
```

demType describes elements, attributes, and associations of the class *DEM*. *TIN* and *DEM* represent terrain surfaces.

8.5 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 8.1 shows the architectural plan of the building including the location of units and walls' length and width. Figure 8.2 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.

The complete version of the example is presented in Appendix E.

8.5.1 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.

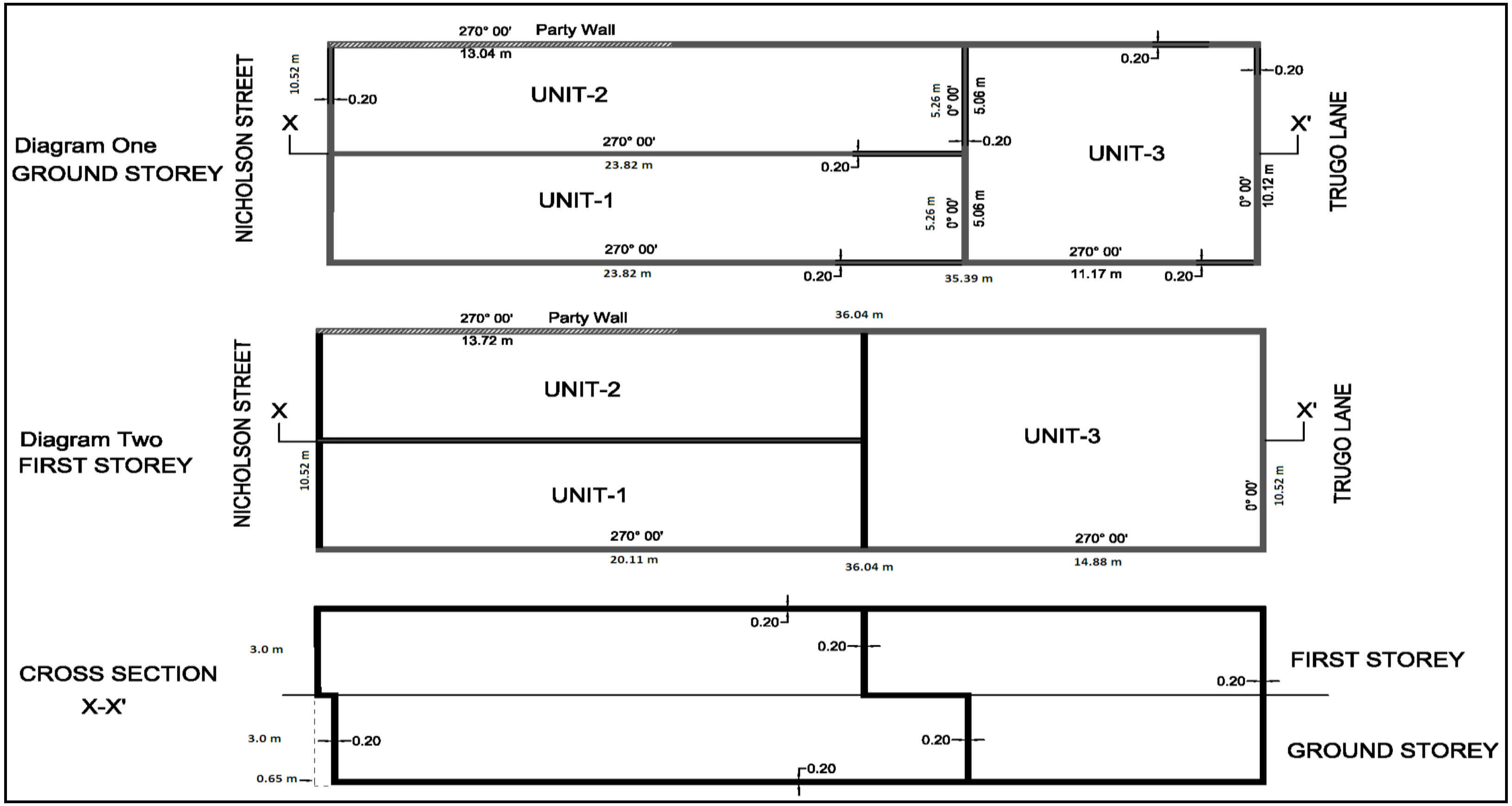


Figure 8.1: Architectural Plan

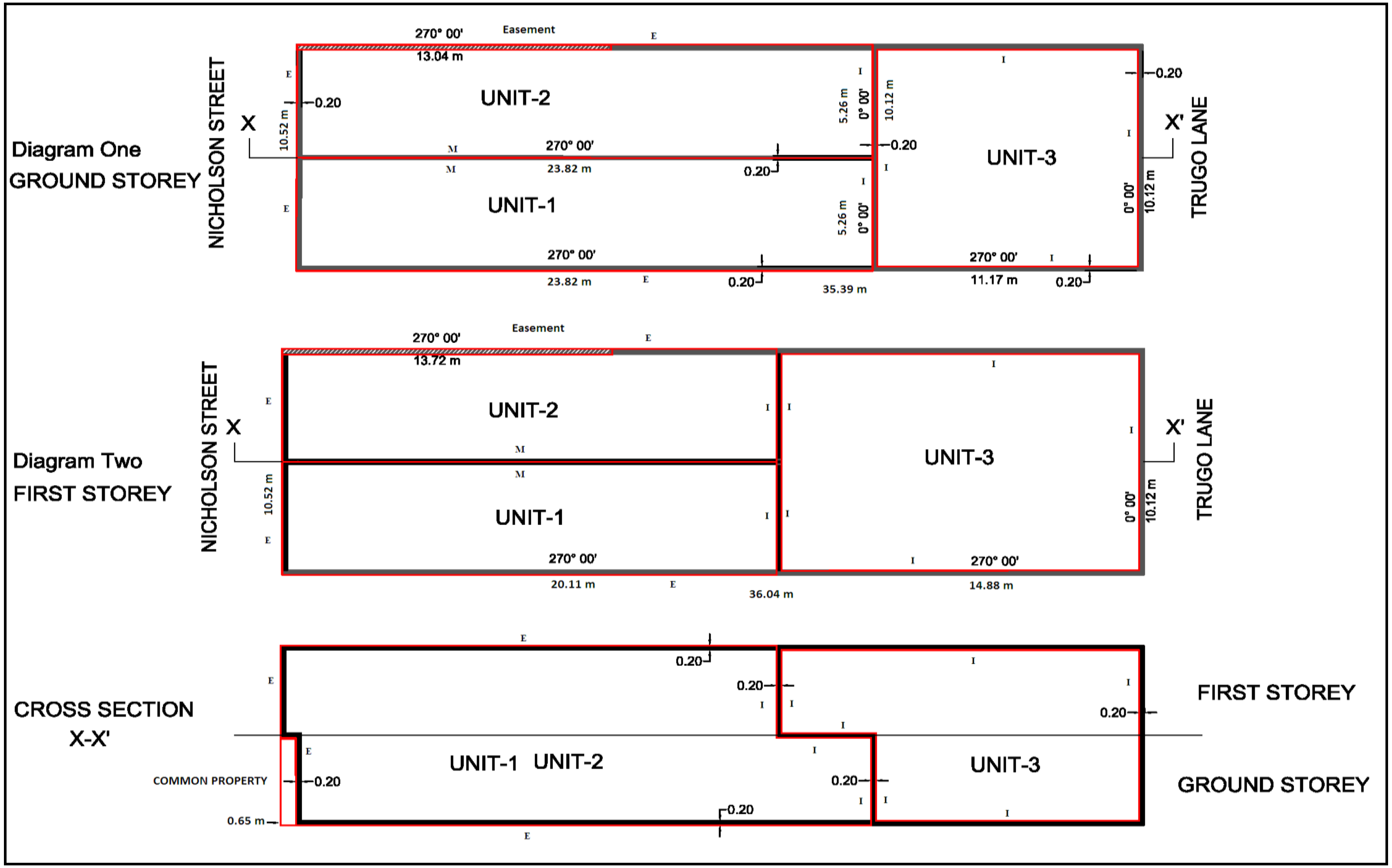


Figure 8.2: Subdivision Plan

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 8.2. 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.

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).

8.5.2 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 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*, *CadastralPoints*, and Terrain schemas are selected for this practice.

```
<!-- =================================== Root Element ================================== -->
<?xml version="1.0" encoding="utf-8"?>
<UrabnCadastralModel
   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.

```
<!-- ================================== 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 representation of the legal world. Therefore, the terrain model (TIN) is provided in the first step as below:

```
   <!-- ======================================= 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 8.3 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.

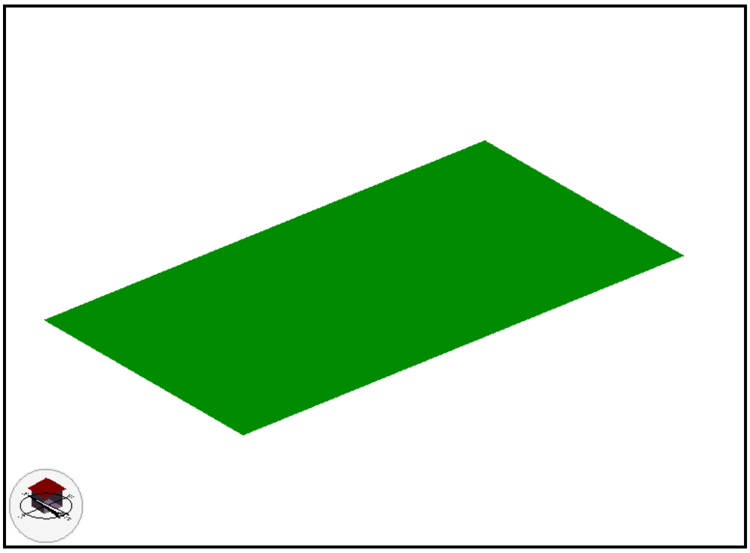


Figure 8.3: Example of terrain model

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 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:

```
            <!-- ===================== 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>
```

```xml
<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  =================================-->
```

Unit_1 is consists of various structural components such as walls, ceilings, and floors. The following step represents how the floor part of *LOT-1*is modelled.

```xml
<!-- ================== PhysicalPropertyObject  =================================-->
<!-- ====================== Floor-Unit1  ====================================-->
<bild:consistsOfStructuralComponent>
  <bild:Floor gml:id="DCDM_Floor_Unit_1">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Floor_Unit-1">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Floor-Unit-1">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Floor_Interior">
                <gml:name>UNIT_1_Floor_Interior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.630 1000.000 0.100 1024.70 1000.000 0.100 1024.70
                    1005.030 0.100 1000.655 1005.030 0.100  1000.630 1000.000 0.100
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Floor_Exterior">
                <gml:name>UNIT_1_Floor_Exterior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.630 1000.000 0 1024.70 1000.000 0 1024.70 1005.030 0
                    1000.655 1005.030 0 1000.630 1000.000 0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_South">
                <gml:name>UNIT_1_Floor_Side_South</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.630 1000.000 0.000 1024.700 1000.000 0.000
                     1024.7001000.000  0.100 1000.630 1000.00 0.100 1000.630 1000.000
                     0.000</gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_North">
                <gml:name>UNIT_1_Floor_Side_North</gml:name>
                <gml:exterior>
```

```
                <gml:LinearRing>
                  <gml:posList>1000.655 1005.030 0.000 1024.700 1005.030 0.000 1024.700
                  1005.030 0.100 1000.655 1005.030 0.100  1000.655 1005.030 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_Right">
              <gml:name>UNIT_1_Floor_Side_Right</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1024.700 1000.000 0.000 1024.700 1005.030 0.000 1024.700
                  1005.030 0.100 1024.700 1000.000 0.100  1024.700 1000.000 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_Left">
              <gml:name>UNIT_1_Floor_Side_Left</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1000.630 1000.000 0.000 1000.655 1005.030 0.000 1000.655
                  1005.030 0.100 1000.630 1000.000 0.100  1000.630 1000.000 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
        </gml:CompositeSurface>
      </gml:surfaceMember>
    </gml:MultiSurface>
  </bild:representedByMultiSurface>
</bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ============================ Wall-South-Unit1 =========================-->
```

Unit_1 consists of various structural components such walls, ceilings, and floors. The following step represents how the floor part of *LOT-1* is modelled.

```
<!-- ============================ Wall-South-Unit1 =========================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_South_Unit_1">
    …
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ============================= Wall-North-Unit1 ========================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_North_Unit_1">
    …
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ======================= Wall_between_Unit1_Unit3_1(upper)  ===============-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_between_Unit1_Unit3_upper">
    …
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ======================= Floor_between_Unit1_Unit3  =====================-->
<bild:consistsOfStructuralComponent>
  <bild:Floor gml:id="DCDM_Floor_between_Unit1_Unit3">
    …
  </bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ============================= Floor_Unit1_Level2  =====================-->
```

```
<bild:consistsOfStructuralComponent>
   <bild:Floor gml:id="DCDM_Floor_Unit1_Level2">
      …
   </bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ============================ Wall_Unit1_Left (Level1)  ==================-->
<bild:consistsOfStructuralComponent>
   <bild:Wall gml:id="DCDM_Wall_Unit1_Side_Left_Level1">
      …
   </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- =========================== Wall_Unit1_Left (Level2)  ===================-->
<bild:consistsOfStructuralComponent>
   <bild:Wall gml:id="DCDM_Wall_Unit1_Side_Left_Level2">
      …
   </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ======================== Ceiling_Unit1 (Level2)  ========================-->
<bild:consistsOfStructuralComponent>
   <bild:Ceiling gml:id="DCDM_Ceiling_Unit1">
      …
   </bild:Ceiling>
</bild:consistsOfStructuralComponent>
<!-- ======================== Space_Unit1 ================================-->
```

Unit_1 does not only consist of various structural components. It also consists of one space, which represents the interior volumetric space of the *Unit_1*. The following step represents how the space of *LOT-1* is created. The unique object id of the *Unit_1*'s *Space* is <bild:Space gml:id="DCDM-Space-Unit-1">. This id was referenced by the LegalPropertyObject <lpo:representedBySolid xlink:href="#DCDM_Space_Unit_1"/> in previous steps.

```
<!-- ======================== Space_Unit1 ================================-->
<bild:consistsOfSpace>
   <bild:Space gml:id="DCDM-Space-Unit-1">
      <bild:representedBySolid>
         <gml:Solid gml:id="DCDM_Space_Unit_1">
            <gml:exterior>
               <gml:Shell>
                  <gml:surfaceMember>
                     <gml:CompositeSurface gml:id="DCDM_Space_Unit-1">
                        <!--  Floor_Unit_1  -->
                        <gml:surfaceMember>
                           <gml:Polygon gml:id="GML_UNIT_1_Floor_Interior_legal">
                              <gml:name>UNIT_1_Floor_Interior</gml:name>
                              <gml:exterior>
                                 <gml:LinearRing>
                                    <gml:posList>1000.630 1000.000 0 1000.655 1005.030 0  1024.70
                                    1005.030 0 1024.70 1000.000 0 1000.630 1000.000 0
                                    </gml:posList>
                                 </gml:LinearRing>
                              </gml:exterior>
                           </gml:Polygon>
                        </gml:surfaceMember>
                        <!--  Wall_South_Unit_1  -->
                        <gml:surfaceMember>
                        </gml:surfaceMember>
                        <!--  Wall_North_Unit_1  -->
                        <gml:surfaceMember>
                           …
                        </gml:surfaceMember>
                        <!--  Wall_between_Unit1_Unit3_lower -->
```

```
                              <gml:surfaceMember>
                                …
                              </gml:surfaceMember>
                              <!-- Wall_between_Unit1_Unit3_upper -->
                              <gml:surfaceMember>
                                …
                              </gml:surfaceMember>
                              <!-- Floor_between_Unit1_Unit3 -->
                              <gml:surfaceMember>
                                …
                              </gml:surfaceMember>
                              <!-- Floor_Unit1_Level2 -->
                              <gml:surfaceMember>
                                …
                              </gml:surfaceMember>
                              <!-- Wall_Unit1_Side_Left_Level1 -->
                              <gml:surfaceMember>
                                …
                              </gml:surfaceMember>
                              <!-- Wall_Unit1_Side_Left_Level2 -->
                              <gml:surfaceMember>
                                …
                              </gml:surfaceMember>
                              <!-- Ceiling_Unit1 -->
                              <gml:surfaceMember>
                                …
                              </gml:surfaceMember>
                            </gml:CompositeSurface>
                          </gml:surfaceMember>
                        </gml:Shell>
                      </gml:exterior>
                    </gml:Solid>
                  </bild:representedBySolid>
                </bild:Space>
              </bild:consistsOfSpace>
            </bild:Unit>
          </bild:consistsOfBuildingPart>
          <!-- ============================= EndOfUnit1 ===================================-->
```

The Unit-1 model is shown in Figure 8.4.

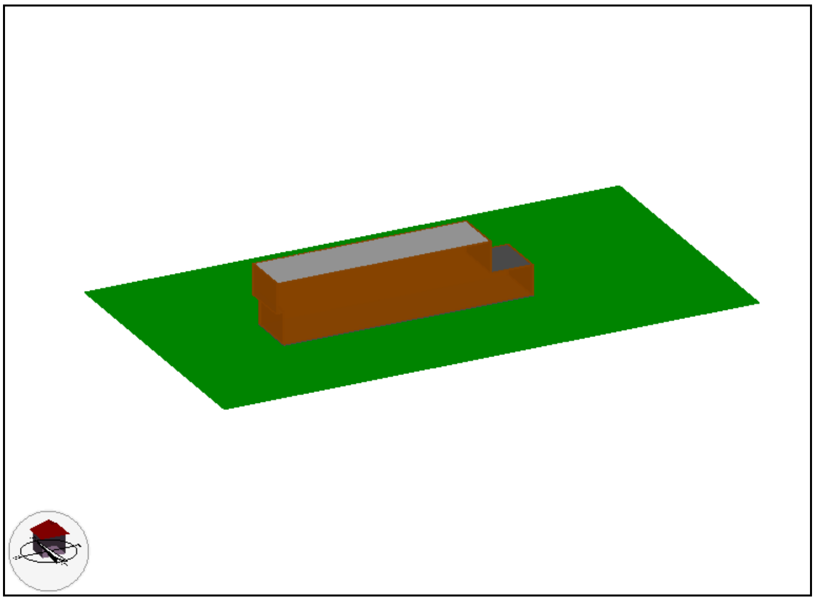


Figure 8.4: Example of the building model, Unit-1

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.

```
<!-- ================================ Unit2 =================================-->
<bild:consistsOfBuildingPart>
  <bild:Unit gml:id="DCDM_Unit_2" landUse="residential" lpoRef="LOT-2">
    <!-- ==================== UNIT_2's Legal Counterpart =========================-->
    <lpo>
      <lpo:LegalPropertyObject gml:id="LOT-2" lpoClass="lot" lpoUnit="single" lpoFormat="3DParcel"
      name="LOT-2" lpoState="created" rrr="ownership" lotEntitlement="35" lotLiability="35">
        <lpo:address>
          <lpo:Address flatNumber="2" propertyNumber="143" streetName="Nicholson"
          streetType="street" Suburb="Footscray" postCode="3011" state="VIC" country="Australia"/>
        </lpo:address>
        <lpo:proprietor>
          <ownr:InterestHolder gml:id="ID_102" pName="Jude Sammonds" share="100" type="person"/>
        </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_2">
       </lpo:representedBySolid>
      </lpo:LegalPropertyObject>
    </lpo>
    <!-- ========================= PhysicalPropertyObject ========================-->
    <!-- ============================ Floor-Unit2 ============================-->
    <bild:consistsOfStructuralComponent>
      <bild:Floor gml:id="DCDM_Floor_Unit_2">
        …
      </bild:Floor>
    </bild:consistsOfStructuralComponent>
    <!-- ======================= Wall-South-Unit2 ============================-->
    <bild:consistsOfStructuralComponent>
      <bild:Wall gml:id="DCDM_Wall_South_Unit_2">
        …
      </bild:Wall>
    </bild:consistsOfStructuralComponent>
    <!-- ======================= Wall-North-Unit2 ============================-->
    <bild:consistsOfStructuralComponent>
      <bild:Wall gml:id="DCDM_Wall_North_Unit_2">
        …
      </bild:Wall>
    </bild:consistsOfStructuralComponent>
    <!-- ================= Floor-between-Unit2-Unit3_ lower (0.10) =================-->
    <bild:consistsOfStructuralComponent>
      <bild:Floor gml:id="DCDM_Floor_between_Unit2_Unit3_Lower">
```

```
          …
        </bild:Floor>
      </bild:consistsOfStructuralComponent>
      <!-- ==================== Wall_between_Unit2_Unit3_1(lower)  ===================-->
      <bild:consistsOfStructuralComponent>
        <bild:Wall gml:id="DCDM_Wall_between_Unit2_Unit3_lower">
          …
        </bild:Wall>
      </bild:consistsOfStructuralComponent>
      <!-- ==================== Wall_between_Unit2_Unit3_1(upper)  ===================-->
      <bild:consistsOfStructuralComponent>
        <bild:Wall gml:id="DCDM_Wall_between_Unit2_Unit3_upper">
          …
        </bild:Wall>
      </bild:consistsOfStructuralComponent>
      <!-- ======================== Floor_between_Unit2_Unit3  ======================-->
      <bild:consistsOfStructuralComponent>
        <bild:Floor gml:id="DCDM_Floor_between_Unit2_Unit3">
          …
        </bild:Floor>
      </bild:consistsOfStructuralComponent>
      <!-- ======================== Floor_Unit2_Level2  ============================-->
      <bild:consistsOfStructuralComponent>
        <bild:Floor gml:id="DCDM_Floor_Unit2_Level2">
          …
        </bild:Floor>
      </bild:consistsOfStructuralComponent>
      <!-- ==================== Wall_Unit2_Left (Level1)  ============================-->
      <bild:consistsOfStructuralComponent>
        <bild:Wall gml:id="DCDM_Wall_Unit2_Side_Left_Level1">
          …
        </bild:Wall>
      </bild:consistsOfStructuralComponent>
      <!-- ================ Wall_Unit2_Left (Level2)  ================================-->
      <bild:consistsOfStructuralComponent>
        <bild:Wall gml:id="DCDM_Wall_Unit2_Side_Left_Level2">
          …
        </bild:Wall>
      </bild:consistsOfStructuralComponent>
      <!-- ======================== Ceiling_Unit2 (Level2)  ==========================-->
      <bild:consistsOfStructuralComponent>
        <bild:Wall gml:id="DCDM_Ceiling_Unit2">
          …
        </bild:Wall>
      </bild:consistsOfStructuralComponent>
      <!-- ========================== Space_Unit2 ==============================-->
      <bild:consistsOfSpace>
        <bild:Space gml:id="DCDM-Space-Unit-2">
          …
        </bild:Space>
      </bild:consistsOfSpace>
    </bild:Unit>
  </bild:consistsOfBuildingPart>
  <!-- ====================== EndOfUnit2 ======================================-->
  <!-- ========================== Unit3  ========================================-->
```


The Unit-1, Unit-1, and Unit-3 models are shown in Figure 8.5.

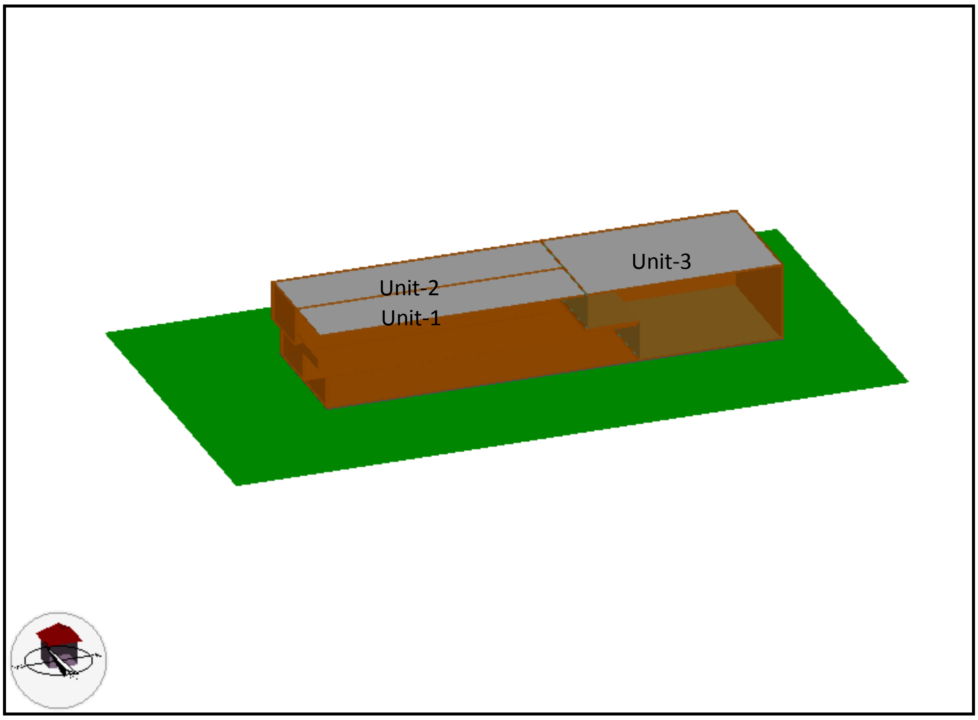


Figure 8.5: Example of the building model, Unit-1, Unit-2, and Unit3

Figure 8.6 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.

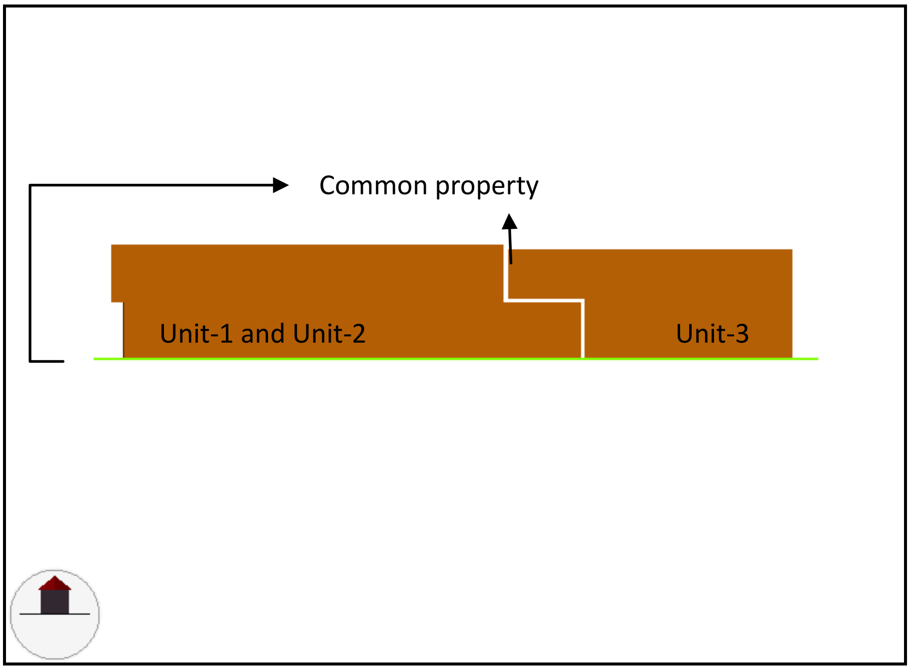


Figure 8.6: Example of the building model, Unit-1, Unit-2, and Unit3

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. Now, The common property of the building is modelled below:

```xml
<!-- ======================== EndOfUnit3 ======================================-->
<!-- ============= CommonProperty_Pathway ======================================-->
<bild:consistsOfBuildingPart>
  <bild:Pathway gml:id="DCDM_CommonProperty" lpoRef="CommonProperty">
    <!-- ================ Pathway's Legal Counterpart ==============================-->
    <lpo>
      <lpo:LegalPropertyObject gml:id="CommonProperty" lpoClass="commonProperty" lpoUnit="single"
      lpoFormat="3DParcel" name="CommonProperty" lpoState="created" rrr="commonOwnership">
        <lpo:legalDocument>
          <lpo:Title folio="725" volume="10564">
            <lpo:locatedAs>
              <lpo:LandDescription plan="SubdivisionPlan" planNo="422525J" lotNo="CP-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_CommonProperty_Pathway">
    </lpo:representedBySolid>
      </lpo:LegalPropertyObject>
    </lpo>
    <!-- ================ PhysicalPropertyObject ==================================-->
    <bild:representedBySolid>
      <gml:Solid gml:id="DCDM_CommonProperty_Pathway">
        <gml:exterior>
          <gml:Shell>
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM_CommonProperty-Pathway">
                <!-- Floor_CommonProperty -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Floor_CommonProperty_legal">
                    <gml:name>Floor_CommonProperty_legal</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1000.00 1000.000 0 1000.00 1010.060 0  1000.655 1010.060 0
                        1000.630 1000.000 0 1000.00 1000.000 0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <!-- Ceiling_CommonProperty -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Ceiling_CommonProperty_legal">
                    …
                  </gml:Polygon>
                </gml:surfaceMember>
                <!-- Wall_CommonProperty_Right -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_CommonProperty_Right_legal">
                    …
                  </gml:Polygon>
                </gml:surfaceMember>
                <!-- Wall_CommonProperty_Left -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_CommonProperty_Left_legal">
                    …
                  </gml:Polygon>
                </gml:surfaceMember>
                <!-- Wall_CommonProperty_North -->
```

```
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Wall_CommonProperty_North_legal">
                                …
                            </gml:Polygon>
                        </gml:surfaceMember>
                        <!--  Wall_CommonProperty_South  -->
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Wall_CommonProperty_South_legal">
                                …
                            </gml:Polygon>
                        </gml:surfaceMember>
                    </gml:CompositeSurface>
                </gml:surfaceMember>
            </gml:Shell>
        </gml:exterior>
    </gml:Solid>
    </bild:representedBySolid>
    </bild:Pathway>
    </bild:consistsOfBuildingPart>
    <!-- ====================End CommonProperty_Pathway ================================-->
    </bild:Building>
  </physicalObjectMember>
  <physicalObjectMember>
    <!-- ========================== Easement_Wall  ========================================-->
```

The party wall in the building as an easement of *Unit-2* is created below.

```
    <!-- ========================== Easement_Wall  ========================================-->
    <bild:Wall gml:id="DCDM_Easement_Wall" lpoRef="Easement">
      <!-- ================== PartyWall's Legal Counterpart  ==================================-->
      <lpo>
        <lpo:LegalPropertyObject gml:id="Easement" lpoClass="easement" lpoUnit="single" lpoFormat="3DParcel"
        name="Easement" lpoState="created" rrr="easement">
          <lpo:legalDocument>
            <lpo:Title folio="725" volume="10564">
              <lpo:locatedAs>
                <lpo:LandDescription plan="SubdivisionPlan" planNo="422525J" lotNo="E-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_Easement_PartyWall">
          </lpo:representedBySolid>
        </lpo:LegalPropertyObject>
      </lpo>
      <!-- ====================== PhysicalPropertyObject  ====================================-->
      <bild:representedBySolid>
        <gml:Solid gml:id="DCDM_Easement_PartyWall">
          <gml:exterior>
            <gml:Shell>
              <gml:surfaceMember>
                <gml:CompositeSurface gml:id="DCDM_Easement-PartyWall">
                  <!--  Floor_Easement  -->
                  <gml:surfaceMember>
                    <gml:Polygon gml:id="GML_Floor_Easement_legal">
                      …
                    </gml:Polygon>
                  </gml:surfaceMember>
                  <!--  Floor_Easement_Level2  -->
                  <gml:surfaceMember>
                    <gml:Polygon gml:id="GML_Floor_Easement_Level2_legal">
                      …
                    </gml:Polygon>
                  </gml:surfaceMember>
                  <!--  Ceiling_Easement  -->
```

```
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_Ceiling_Easement_legal">
                            …
                          </gml:Polygon>
                        </gml:surfaceMember>
                        <!-- Wall_Easement_Right -->
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_Wall_Easement_Right_legal">
                            …
                          </gml:Polygon>
                        </gml:surfaceMember>
                        <!-- Wall_Easement_Left -->
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_Wall_Easement_Left_legal">
                            …
                          </gml:Polygon>
                        </gml:surfaceMember>
                        <!-- Wall_Easement_Left_Level2 -->
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_Wall_Easement_Left_Level2_legal">
                            …
                          </gml:Polygon>
                        </gml:surfaceMember>
                        <!-- Wall_Easement_Left_Level2 -->
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_Wall_Easement_North_legal">
                            …
                          </gml:Polygon>
                        </gml:surfaceMember>
                        <!-- Wall_Easement_Left_Level2 -->
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_Wall_Easement_South_legal">
                            …
                          </gml:Polygon>
                        </gml:surfaceMember>
                      </gml:CompositeSurface>
                    </gml:surfaceMember>
                  </gml:Shell>
                </gml:exterior>
              </gml:Solid>
            </bild:representedBySolid>
          </bild:Wall>
          <!-- =======================End Easement Wall ============================-->
        </physicalObjectMember>
      </UrbanModel>
    </physicalModel>
    <!-- ======================== Legal Model ====================================-->
```

The common property and easement are visualised in the Figure 8.7.

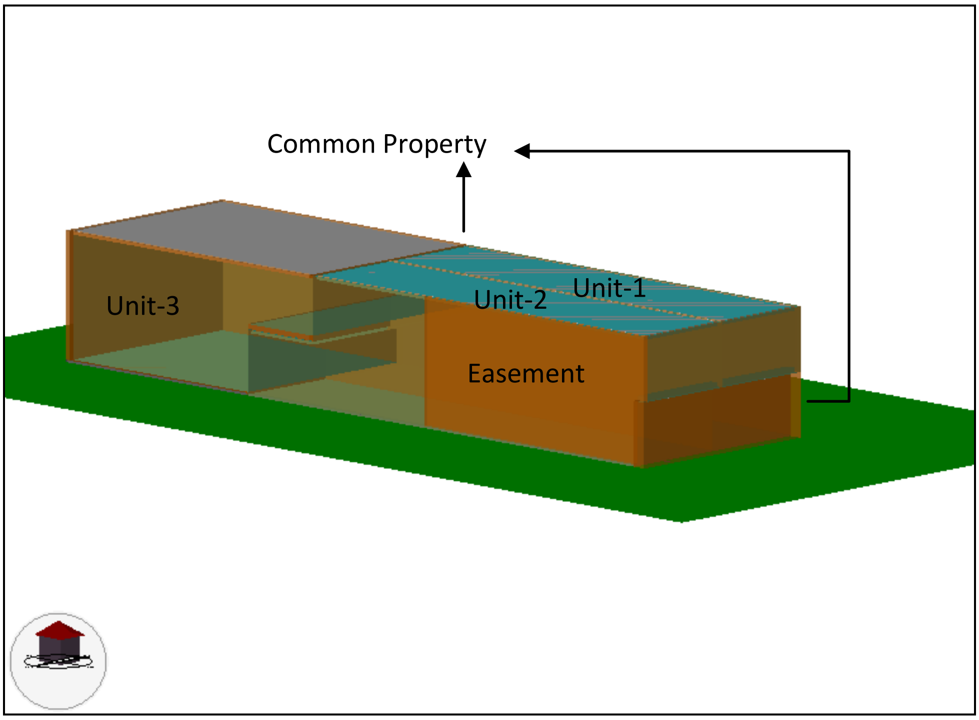


Figure 8.7: Example of the building model, common property and easement

Cadastral points are the important parts of the cadastral models. They are introduced in the 3DCDM in the legal hierarchy of the 3DCDM model. The following codes represent how they are modelled in the 3DCDM model.

```
<!-- ========================== Legal Model ======================================-->
<legalModel>
  <CadastralModel>
    <legalObjectMember>
      <!-- ==================== ReferencePoint ======================================-->
      <cpm:CadastralPoints gml:id="CPM_ID1">
        <cpm:referencePointMember>
          <!-- CadastralPoints Unit1 -->
          <cpm:CadastralPoint name="U1_L1_W1_A1" state="existing">
            <cpm:referencePoint>
              <gml:Point gml:id="U1_L1_W1-A1">
                <gml:pos>1000.630 1000.000 0.0</gml:pos>
              </gml:Point>
            </cpm:referencePoint>
          </cpm:CadastralPoint>
          <cpm:CadastralPoint name="U1_L1_W2_B2" state="existing">
            <cpm:referencePoint>
              <gml:Point gml:id="U1_L1_W2-B2">
                <gml:pos>1024.90 1000.000 0.0</gml:pos>
              </gml:Point>
            </cpm:referencePoint>
          </cpm:CadastralPoint>
          …
        </cpm:referencePointMember>
      </cpm:CadastralPoints>
    </legalObjectMember>
    <legalObjectMember>
    <!-- ==================== End of ReferencePoint ================================-->
    <!-- ======================== Surveying ======================================-->
```

Survey information also modelled in the legal hierarchy of the 3DCDM model. The surveyor information, instrument setup, and measurements are included in the 3DCDMmodel and represented below:

```
<!-- ==================== End of ReferencePoint =================================-->
<!-- ======================== Surveying =====================================-->
  <suvy:Survey gml:id="survey_ID1">
    <suvy:surveyedBy>
      <suvy:surveyor name="Peter John" surveyorFirm="GlobeArray" regNumber="8145"/>
    </suvy:surveyedBy>
    <suvy:initialisation>
      <suvy:SetupInstrument instrumentHeight="0" stationName="IS-1" setupID="IS-1">
        <suvy:referencePoint>
          <suvy:SetupPoint pntRef="U1_L1_W1_A1"/>
        </suvy:referencePoint>
      </suvy:SetupInstrument>
      <suvy:SetupInstrument instrumentHeight="0" stationName="IS-2" setupID="IS-2">
        <suvy:referencePoint>
          <suvy:SetupPoint pntRef="U3_L2_W8_2"/>
        </suvy:referencePoint>
      </suvy:SetupInstrument>
      <suvy:SetupInstrument instrumentHeight="0" stationName="IS-3" setupID="IS-3">
        <suvy:referencePoint>
          <suvy:SetupPoint pntRef="U3_L1_W45_1_2"/>
        </suvy:referencePoint>
      </suvy:SetupInstrument>
         …
    </suvy:initialisation>
    <suvy:observation>
      <suvy:ObservationGroup id="OG-1">
        <!-- Surveying LOT1-Level2 -->
        <suvy:reducedLineObservation>
          <suvy:RedHorizontalLineObservation name="RHLO-1" setupID="IS-1" targetSetupID="IS-2"
          azimuth="270.00" horizDistance="23.82" purpose="normal"/>
        </suvy:reducedLineObservation>
        <suvy:reducedLineObservation>
          <suvy:RedHorizontalLineObservation name="RHLO-2" setupID="IS-2" targetSetupID="IS-3"
          azimuth="0.00" horizDistance="5.26" purpose="normal"/>
        </suvy:reducedLineObservation>
        <suvy:reducedLineObservation>
          <suvy:RedHorizontalLineObservation name="RHLO-3" setupID="IS-3" targetSetupID="IS-4"
          azimuth="270.00" horizDistance="23.82" purpose="normal"/>
        </suvy:reducedLineObservation>
        <suvy:reducedLineObservation>
          <suvy:RedHorizontalLineObservation name="RHLO-4" setupID="IS-4" targetSetupID="IS-1"
          azimuth="0.00" horizDistance="5.26" purpose="normal"/>
        </suvy:reducedLineObservation>
        <!-- Surveying LOT2-Level2 -->
        <suvy:reducedLineObservation>
          …
        </suvy:reducedLineObservation>
        <!-- Surveying LOT3(Over Lot1)-Level2 -->
        <suvy:reducedLineObservation>
          …
        </suvy:reducedLineObservation>
      </suvy:ObservationGroup>
    </suvy:observation>
  </suvy:Survey>
</legalObjectMember>
<!-- ======================== End of Surveying ==================================-->
  </CadastralModel>
</legalModel>
<!-- ======================= End of Legal Model ===================================-->

</UrabnCadastralModel>
<!-- ==========================End of  the 3DCDM model ===============================-->
```

8.6 EVALUATION OF THE 3DCDM MODEL

In order to evaluate the 3DCDM model, the conceptual model quality evaluation framework is used to investigate different aspects of the 3DCDM model. This framework provides certain principles and quality factors which can be used to evaluate the 3DCDM model. These principles and quality factors state that data models should (West, 2011):

- meet the data requirement
- be clear and unambiguous to all (not just the authors)
- be stable in the face of changing data requirements
- be flexible in the face of changing business practices
- be reusable by others
- be consistent with other models covering the same scope (if they were developed following these principles)
- be able to integrate data from different data models.

Quality of models is very important because models represent user requirements and are used as bases for building systems. Model quality is considered from two perspectives. They are process quality and product quality (Moody, 1998).

For product quality, the focus is on characteristics of the final product. It is used to inspect the problems and deficiencies of the final product. While the process quality does not focus on the final product, its focus is on the process which is used to build the product (Alkhaldi, 2012).

An international standard has now been established for evaluating the quality of software products. However there is no equivalent standard for evaluating the quality of conceptual models. While a range of quality frameworks have been proposed in the literature, none of these have been widely accepted in practice and none has emerged as a potential standard (Moody, 2005).

Various quality evaluation frameworks have been developed such as (Kesh, 1995; Assenova & Johannesson, 1996; Shanks, 1997; Moody & Shanks, 1998; Poels & Dedene, 2000). Among them, Moody (2003) developed a conceptual model quality evaluation framework which highlights eight quality factors: completeness, integrity, flexibility, understandability, correctness, simplicity, integration and implementability. Every factor has a detailed metric for its evaluation. This framework was applied to ensure process quality in this research. Various review meetings were held during the model development stage.

The definitions of the quality factors are (Moody, 2003):

- Correctness was defined as whether the model conforms to the rules of the data modelling technique (i.e. whether it is a valid data model). This includes diagramming conventions, naming rules, definition rules, rules of composition and normalisation.

- Completeness refers to whether the data model contains all information required to support the required functionality of the system.

- Integrity is defined as whether the data model defines all business rules that apply to the data.

- Simplicity means that the data model contains the minimum possible entities and relationships.

- Flexibility is defined as the ease with which the data model can cope with business and/or regulatory change.

- Integration is defined as the consistency of the data model with the rest of the organisation’s data.

- Understandability is defined as the ease with which the concepts and structures in the data model can be understood.

- Implementability is defined as the ease with which the data model can be implemented within the time, budget and technology constraints of the project.

In this framework, each quality factor is rated using a 1–5 scale (1 = poor; 5 = excellent), which was used by the model reviewers. The result of the overall subjective ratings can be presented in the form of Radar or Kiviat chart.

The 3DCDM was validated using a case study approach, which enabled the definition of quality factors (Section 8.5). The 3DCDM was rated based on these factors and the results are listed in Table 8.14. The overall rating of the 3DCDM model is 4. This is a satisfactory rating given the current lack of available and appropriate 3D data. However, it is likely that with subsequent use and implementation, and relevant feedback, the correctness value will improve over time. In the case study, a two-storey building was used to consider relevant legal (ownership boundaries, ownership information, common properties, and an easement) and physical information (the width, length, and height of walls, roofs, and ceilings). An arbitrary coordinate system was used to extract all coordinates of the required points. From these points various properties such as width and length of the walls and units, were determined. This information was then inserted into the appropriate XML schemas such as Building, LegalpropertyObject, InterestHolder, Survey, CadastralPoints, and Terrain to demonstrate the validity of the 3DCDM to model and produce the 3D legal objects of the building and their physical counterparts. The result of this exercise showed that all 3D legal objects of the building (Lot1, Lot2, Lot3, Common properties, and the easement) and their corresponding physical objects can be effectively modelled using the 3DCDM model.

Table 8.14: The 3DCDM model quality factors

Quality Factor	Description	Rate (1 = poor; 5 = excellent)
Correctness	The 3DCDM model was developed based on the ISO/TC standard 19103:2006 (Geographic information-Conceptual schema language) and conforms with its technical specifications. The 3DCDM model follows diagramming conventions, naming rules, and all other	3

	necessary conditions. However, the 3DCDM model requires inspection by a professional data modeller.	
Completeness	The 3DCDM model was developed based on the business analysis represented in the Chapter 6. In this stage, the model supports most of the user requirements of the 3D cadastres. Requirements are changing. Therefore, it is essential to update the user requirements after developing the 3DCDM model.	4
Integrity	In this stage, the 3DCDM model defines limited business rules that apply to the data. The 3DCDM model should be assessed by the users to identify how well the model defines the business rules.	3
Simplicity	The 3DCDM model contains the minimum possible entities and relationship mostly because it utilises the concept of Legal Property Object. However, the 3DCDM model requires inspection by a professional data modeller.	4
Flexibility	Fully functioning 3D cadastres are yet to be implemented the world. This model can facilitate the implementation of the 3D cadastre. Therefore, it is not possible to truly discuss how the model would cope with business changes. However the 3DCDM model was developed based on the idea that 3D cadastres should be developed in such a way that it can help other applications, such as property management and urban planning.	4
Integration	The 3DCDM model was developed for managing stratified land ownership rights. On the one hand, the 3DCDM model requires 3D data (X,Y,Z) to be able to create and represent the 3D models. On the other hand, architectural or engineering plans are required to create the physical object on the data model. However, most of the jurisdictions maintain limited 3D data or physical information.	3
Understandability	The 3DCDM model structure is easy to understand. The 3DCDM model supports semantics, which help to realise	4

	the different part of the model.	
Implementability	Lack of the required data impedes the implementation of the 3DCDM model. Technology is not advanced in creating and manipulating of 3D models. Creating 3D models is time consuming and expensive. However, the 3DCDM model works well if the required data is available.	4

Figure 8.8 illustrates the result of the overall subjective ratings of the 3DCDM model, which is represented in a Radar chart.

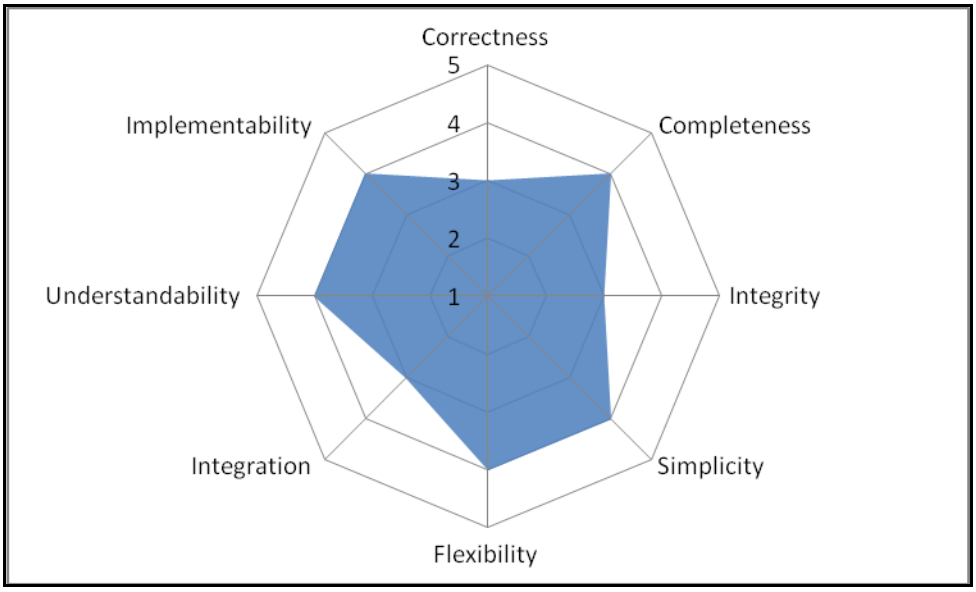


Figure 8.8: Subjective ratings of the 3DCDM model quality

The subjective ratings shown in Figure 8.8 clearly indicate what the strengths and weaknesses are in the model. Ratings below 3 are considered ‘poor’ and ratings above 3 are ‘good’. This provides feedback to the analyst as to where the model needs to be improved. Subjective quality ratings are useful for improving the quality of the model, choosing between alternatives and comparison over time improves processes.

Correctness of the 3DCDM model scored a rating of 3. This moderate rating is acceptable because the 3DCDM was developed based on the ISO/TC standard 19103:2006 (Geographic information-Conceptual schema language) and conforms with its technical specifications. The 3DCDM model follows diagramming conventions, naming rules, and all other necessary conditions. However, it is likely that with subsequent use and implementation, and relevant feedback, the correctness value will improve over time.

Completeness of the 3DCDM model scored a rating of 4. This is a satisfactory rating. The 3DCDM was based on the business analysis represented in the Chapter 6. In this stage, the model supports most of the user requirements of the 3D cadastres. Requirements are always changing; therefore, it is essential to update the user requirements over time.

Integrity of the 3DCDM model scored a rating of 3. This is an acceptable rating given the current lack of available and appropriate 3D data limits defining business rules that apply to the data.

Simplicity of the 3DCDM model scored a rating of 4. The 3DCDM model contains the minimum possible entities and relationship (associations) mostly because it utilises the concept of Legal Property Object.

Flexibility of the 3DCDM model scored a rating of 4. The 3DCDM model was developed based on the idea that 3D cadastres should be developed in such a way that it can help other applications, such as property management and urban planning. Although the 3DCDM model can facilitate the implementation of the 3D cadastre, it is not possible to truly discuss how the model would cope with business changes.

Integration of the 3DCDM model scored a rating of 3. This moderate rating is acceptable because most of the jurisdictions maintain limited 3D data or physical information. The 3DCDM model manages stratified and overlapping property ownership rights. On the one hand, the 3DCDM model requires 3D data (X,Y,Z) to be able to create and represent the 3D models. On the other hand, architectural or engineering plans are required to create the physical object on the data model.

Understandability of the 3DCDM model scored a rating of 4. The 3DCDM model structure is easy to understand. The 3DCDM model supports semantics, which help to realise the different part of the model.

Implementability of the 3DCDM model scored a rating of 4. The 3DCDM model works well if the required data is available. However, lack of the appropriate data (3D legal and physical data) limits the implementation of the 3DCDM model.

8.7 CHAPTER SUMMARY

In this chapter, 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 in this thesis. 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 summarised in the Table 8.1. URIs help the model users to access the XML schemas and utilise 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. The complete version of the example is presented in Appendix E.

Evaluation of the 3DCDM model was presented as the last step in this chapter. The methodology to evaluate the quality of the 3DCDM model was to rate eight quality factors using a scale of 1 to 5 by the model reviewers. The evaluation of the 3DCDM model shows that the model is complete, correct, simple, flexible, and understandable. The overall rating of the 3DCDM model is 4, which is above average. This is an acceptable rating given the current lack of available and appropriate 3D data and means that there are limited opportunities to test this data model using real data to understand the scope for improvement. The score is promising for future research purposes.

CHAPTER 9 – CONCLUSIONS AND RECOMMENDATIONS

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

This chapter is the final stage of the scientific method that is applied in this dissertation (see Chapter 4). It aims to: highlight the significance of the research work, theory and practice; reflects on the original research problem; and determines the successes and limitations of the design used to develop the 3DCDM model. It also suggests directions for future research efforts and discusses the potential research opportunities in the area of managing stratified land ownership rights, restrictions, and responsibilities.

9.2 RESEARCH AIM AND OBJECTIVES

As described in Chapter 1, the central aim of this dissertation was to:

"Develop and implement a data model to enable the capture, storage, editing, querying, analysis and support visualisation of 3D land rights, restrictions and responsibilities in cadastres."

In Chapters 6, 7, and 8, a new 3D cadastral data model, which was called 3DCDM, was conceptualised and developed through the identification of user requirements and data elements of 3D cadastres.To develop the 3DCDM model, the data-modelling development cycle approach was used.

The data modelling-development cycle usually begins at mapping the concepts and their relationships of the real world to a conceptual model. The conceptual data model is created by gathering requirements from various sources such as business documents, discussion with technical teams, business analysts, management experts and end users. The conceptual data model is then translated into a logical data model, which documents structures of the data that can be implemented as a schema or in a database. The last step in data modelling involves transferring the logical data model to a physical data model that organises the data as schema instances or into tables.

To achieve the research aim, a scientific method was utilised in this dissertation. The scientific method involves identifying a problem, conducting background research, generating theories or hypotheses, analysing hypotheses by breaking it down into research questions; creating alternative solutions or developing scientific approaches to answer each question (method); test the hypotheses by building a prototype or by doing an experiment; redesigning the method as necessary; analysing the results and drawing conclusions.

The advantages of using a scientific method is to take a series of steps collectively and over time to ask and answer scientific questions by making observations and doing experiments about the research project.

In this regard, six popular and important cadastral data models were reviewed and assessed to understand how they manage stratified land rights, restrictions, and responsibilities and their physical counterparts.

Overall, it was concluded that the cadastral data models vary among jurisdictions since the applications and purposes of cadastres vary in each jurisdiction. Cadastral data models rely on the basic building block of a 2D land-parcel and have been developed based on the definition of a 2D land-parcel. Those cadastres that support 3D RRRs do not use solid representation and are not semantically rich for interoperability purposes. None of them integrate and mode physical counterparts of legal objects inside the model.

In addition, a Victorian, Australian case study provided better understanding of the current practice of 3D property registration and 3D data elements.

The research proposed a 3D Cadastral Data Model (3DCDM) which is a semantic data model for representing 3D legal and physical information that can be shared over different applications. The data model is developed based on the ISO standard and UML modelling language is used to specify the data model.

3DCDM model has two hierarchies, legal and physical, which are linked in the model. The legal hierarchy is based on Legal Property Object concepts and the physical hierarchy defines the classes and relations for the most relevant objects such as buildings and utility networks with respect to their geometric and semantic properties. Use of this model facilitates implementation of 3D cadastres and increases its usability for different applications.

The 3DCDM model was successfully developed and implemented in reference to the requirements and data elements of 3D cadastres. The model was then assessed against factors of a data modelling quality framework. The evaluation of the 3DCDM model shows the model is almost a complete, correct, simple, flexible, and an understandable data model. However, lack of available and required 3D data and 3D modelling technologies impede the implementation of the data model. This problem also decreases the consistency of the data model with the rest of the organisations' data.

The objectives of the research aim will now be reviewed and discussed.

9.2.1 OBJECTIVE 1: TO INVESTIGATE CONCEPT, DEFINITION, AND REQUIREMENTS OF 3D CADASTRES

Study of the concept, definition, and requirements of 3D cadastres assisted in the discovery of the problems of current cadastres (2D cadastres) in regards to managing stratified land ownership rights, restrictions, and responsibilities and the need for developing 3D cadastres.

Chapter 2 discussed that current cadastral systems are two dimensional (2D cadastre), that is, geometric and descriptive information are based on 2D land parcels, even if stratified rights, restrictions, and responsibilities (RRRs) are situated above or under the land parcels. They are successfully used for fiscal and legal purposes. However, 2D cadastres cannot effectively represent the complexities of reality. They are not able to manage and represent land ownership rights, restrictions and responsibilities in a 3D context.

The outcome of Objective 1 highlighted a number of issues associated with the implementation of 3D cadastres. Lack of a comprehensive and implementable data models was identified as one of the issues along with legal and institutional issues.

A 3D cadastral data model provides: exploration of the different parts of 3D cadastres (objects, elements, attributes, and constraints) and how they are arranged; organisation and provision of documents and practical guidelines for land surveying professionals; simplification of the process of implementing 3D cadastres; promotion of standards and a common language within the land administration user communities; foundation of a 3D cadastre database; facilitation of the exchange of data and the integration of similar datasets, and ease data sharing and interoperability; and understanding data requirements of involved parties

9.2.2 OBJECTIVE 2: TO INVESTIGATE AND ASSESS CURRENT CADASTRAL DATA MODELS

Review and assessment of current cadastral data models facilitated in the investigation of the advantages and deficiencies of current cadastral data model in terms of managing 3D data and the requirements of 3D cadastres.

Chapter 3 discussed that since land administration requirements differ among the different jurisdictions, various cadastral data models have been developed around the world. A qualitative assessment results of the current cadastral data models was conducted to identify issues, obstacles and complications as well as successful experiences and best practices in accommodating the requirements of 3D cadastres.

The outcome of Objective 2 emphasised that the cadastral data models vary among jurisdictions since the applications and purposes of cadastres vary in each jurisdiction. Cadastral data models rely on the basic building block of a 2D land-parcel and have been developed based on the definition of a 2D land-parcel. Those that support 3D RRRs do not use solid representation and are not semantically rich for interoperability purposes. None of them integrate and mode physical counterparts of legal objects inside the model.

9.2.3 OBJECTIVE 3: TO IDENTIFY THE USER REQUIREMENTS AND MAIN DATA ELEMENTS OF 3D CADASTRES

Identifying the user requirements and main data elements of 3D cadastres is an important step in the data-modelling development cycle. This Objective covered the first and second steps of the data modelling development cycle, which are a business analysis and conceptual data modelling, for development of the 3DCDM model.

The outcome of Objective 3 highlighted the user needs and requirements of 3D cadastres. Requirements and data elements of the 3D cadastre were specified in the business analysis step. Needs for digital 3D data, multi-purpose 3D cadastres (which requires both legal and physical objects); different methods of 3D data acquisition (using coordinated cadastral marks, architectural plans); representation of all possible interests including land use; maintaining interest holder's personal information and detailed information, which is currently kept in volume folios or other legal documents; support of various 3D primitives to maintain geometrical/topological requirements; provision of accurate and reliable data for 3D titling system; and maintenance of temporal information were identified as the main user requirements of 3D cadastres.

In addition to the recognition of the users' requirements, the main data elements of 3D cadastres were identified to reveal the potential objects of the 3D cadastral data model and assist in the re-engineering of data models to respond to the users' requirements. They are: 3D right object, 3D physical object, interest holder, title, surveying information, survey plan, and architectural plan information.

Chapter 5 described the current practice of 3D property registration in Victoria, Australia, using a case study. Investigating the case study helped to identify the data types and processes involved registering a 3D property.

Chapter 6 discussed the business analysis that was used to identify the user requirements of 3D cadastres. The basic objectives of the business analysis involved: gathering and defining basic objects and data elements; describing the information about the data elements and the relationships among them; and comprehensively documenting all of the requirements

9.2.4 OBJECTIVE 4: TO DESIGN AND DEVELOP A 3D CADASTRAL DATA MODEL SUITABLE FOR LAND ADMINISTRATION SYSTEM

Developing a 3D cadastral data model lead to the implementation of the findings achieved in Objective 3 and addressed the problems of current cadastral data models in terms of managing stratified land ownership rights, restrictions, and responsibilities.

The result of Objective 4 was a logical model of the 3DCDM. This model was presented as the third step of 3D cadastral data-modelling development cycle in Chapter 7. The aim was to explore all elements and components of the 3DCDM model including its classes, attributes, and associations.

The logical model of the 3DCDM model was decomposed into two hierarchies; legal and physical. The legal hierarchy consisted of *3DCDM LegalPropertyObject Model*, *3DCDM InterestHolder Model*, *3DCDM Survey Model*, and *3DCDM CadastralPoints Model*

The physical hierarchy of the 3DCDM consisted of *3DCDM Building Model*, *3DCDM Land Model*, *3DCDM Tunnel Model*, *3DCDM UtilityNetwork Model*, *3DCDM PhysicalPropertyObject Model*, and *3DCDM Terrain Model.*

These sub-models (modules) in addition to *3DCDM Geometry Model* and *3DCDM Root Model* created the 3DCDM model. Having separated models prevented users from utilising unnecessary models.

9.2.5 OBJECTIVE 5: TO DEVELOP A PROTOTYPE TO TEST THE 3D CADASTRAL DATA MODEL USING A CASE STUDY

The outcome of Objective 5 showed a successful implementation of the 3DCDM model. A prototype system put forward the idea of using 3D parcel, integrating legal and physical counterparts, and utilising semantics in a 3D cadastral data model.

The developed logical data model of the 3DCDM model in Chapter 7 was implemented in Chapter 8 using the dataset of a case study. Eleven XML schemas were developed in Chapter 8 for implementation of the 3DCDM model as the physical step of data-modelling development cycle. The dataset was implemented as a schema instance. The prototype illustrated how the 3DCDM models the physical objects of a building and their legal counterparts. Evaluation of the 3DCDM model as the outcome of Objective 5 highlighted completeness, correctness, simplicity, flexibility, and understandability of the 3DCDM model.

9.3 CONCLUSION ON RESEARCH PROBLEM

Cadastres are regarded as the engine of land administration systems to help manage interests in land and its resources. 3D developments of land are common and put enormous pressure on current land administration systems, which are equipped with the cadastres that are only able to maintain 2D spatial information.

The research problem was that:

"In dense urban populated areas, current land administration systems use 2D cadastral data models which

a) do not support 3D data do not efficiently facilitate representation and analysis of 3D data.

b) are not semantically enriched

c) do not incorporate physical objects.

Therefore they cannot adequately manage and represent the spatial extent of stratified land rights, restrictions and responsibilities (RRRs)."

This research problem was addressed through conceptualisation, development and implementation of the 3DCDM model capable of accommodating 3D parcel, integrating legal and corresponding physical objects, and utilising semantics. The 3DCDM model has two hierarchies: legal and physical. The legal hierarchy of the 3DCDM employed the Legal Property Object to be able to accommodate ever-growing numbers of interest in land, independently from each other. The physical hierarchy of the 3DCDM model consisted of relevant urban object such as buildings, land, tunnels, and utility networks.

Use of the 3DCDM model facilitated implementation of 3D cadastres and increased its usability for different applications.

9.4 KEY FINDINGS AND CONTRIBUTIONS TO KNOWLEDGE

This research revealed a need for 3D cadastres to manage ever-growing stratified land ownership rights, restrictions, and responsibilities in urban populated areas. This was achieved by describing the problems of the current cadastral systems. It was explained that the 2D cadastral systems serves well in simple buildings, and ground level villa unit developments, but management of modern cityscapes would benefit from much more descriptive capacities in the land administration and titling systems.

Moreover, this research described that the 3D cadastres are not only useful for cadastral applications, such as managing registering of 3D RRRs, but they are also functional for different applications such as city space management and property management in 3D.

Extending the usability of 3D cadastres to support further applications, this research proposed the integration of 3D physical objects with the 3D legal objects in 3D cadastres. This integration was the main clue for proposing a new data model to support the new requirements of the 3D cadastres.

Three main aspects of 3D cadastres were described in this research for implementation purposes in each jurisdiction. They were legal, institutional, and technical. Legal systems would support registration and representation of 3D properties to meet the demands for multiple ownerships of land and buildings. Institutional aspects would provide regulations for defining 3D property rights, mechanisms for acquisition of 3D data, and the tasks and responsibilities of the public and private sectors. Technical aspects such as 3D data capture, visualising, updating and modelling would facilitate the development and implementation of 3D cadastre.

The most popular cadastral data models were reviewed and assessed in this research in order to identify how they are managing 3D data. It was illustrated that the existing cadastral data models vary among jurisdictions since the applications and purposes of cadastres vary in each jurisdiction. Cadastral data models rely on the basic building block of a 2D land-parcel and have been developed based on the definition of a 2D land-parcel. Those that support 3D RRRs do not use solid representation and are not semantically rich for interoperability purposes. None of them integrate and use the physical counterparts of legal objects inside the model.

Based on the specifications of 3D cadastral data models and problems of current cadastral data models, three underlying principles were proposed in this research. These principles were used as a foundation to design and develop the 3D cadastral data model (3DCDM).

This research also specified the requirements and data elements of the 3D cadastre. These items were identified in the business analysis step of 3D cadastral data-modelling development cycle.

Finally, this research introduced the 3DCDM model as a 3D cadastral data model, which supports the requirements of 3D cadastres. The 3DCDM was developed based on the advanced principles of 3D cadastral data modelling. The conceptual, logical, and physical models of the 3DCDM model were developed. Eleven XML schemas were developed for the implementation purpose of the 3DCDM.

9.5 ASSUMPTIONS AND LIMITATIONS

Since every jurisdiction could have its own cadastral data model, a few of them were selected for the comparison purposes. The reason was, they were the most popular cadastral data models that were accessible and available in English language.

An incremental approach with a continual expert reviewing during a period of time is one of the most efficient methodologies. This approach does not work in this research, because of the time restriction.

While the research design has been fully justified in this chapter, it is worth noting a number of limitations. These are predominately time and resource constraints. Firstly, no case studies were conducted outside Australia. An in-depth case study of a Western European or North American jurisdiction would have provided additional validation of the Australian case study results. Many Western European (e.g. Netherlands) jurisdictions have started 3D cadastres. Also, future research is required to validate the data model based on the international terminologies (Paasch & Paulsson, 2011).

Secondly, no in-depth studies of emerging users and land information providers were conducted. Emerging users include the utility network authorities, developers, real estate agents, local councils, emergency services, property management services, and ordinary people (interest holders). Industry bodies could have been surveyed to gain an understanding of information needs. Individual organisations could have been consulted to assess any innovative solutions for managing stratified RRRs. The users are outside the circle of cadastre and land administration professionals should be considered in this investigation, however in this stage, as mentioned before, land registries, surveyors, and related organisations such as ICSM are amongst the intended users.

Perhaps these limitations could be used as starting points for future research in the area.

9.6 FUTURE DIRECTIONS AND RECOMMENDATIONS

The outcomes of this research highlighted the following directions for further investigation in the future.

Firstly, the key to implement the 3DCDM model uses coordinate base data. The 3DCDM geometry model requires lists of coordinates to create 2D and 3D objects. This information should normally be provided through the architectural plans. However, to model the physical and legal objects of a city or an area, a global coordinate system will be required. The implementation of the 3DCDM model requires changes in the provision of architectural plans.

Second, there is a need to change the way licensed surveyors produce subdivision plans. The introduction of the 3DCDM model will be the change of the current practice of acquiring legal boundaries. Subsequently, the current legislations (land registration laws and regulations) should be modified to support 3D digital data.

Thirdly, a Land Administration Domain Model (LADM) was published as an official International ISO Standard. This standard is quite important for the 3D Cadastre developments. It covers the basic information-related components of land administration. It is important to improve the 3DCDM model in order conform to the LADM.

Fourthly, recently a quiet revolution has been taking place that will fundamentally change managing cities utilising Building Information Models (BIM) and 3D city models (CityGML). The focus of these models is on the physical and functional characteristics of urban facilities. Integration of legal information with physical information in these models would maximise the usability of the BIM and CityGML. For example, developing a CityGML ADE (Application Domain Extension) based on the findings of this research will be the future direction in 3D city modelling.

Fifthly, Australian jurisdictions are using ePlan to model the subdivision plans and LandXML as a transfer standard to convert paper-based subdivision plans to digital XML based files. The ePlan model has not been fully designed and exercised to support 3D objects, although it includes Volumetric and Strata (Building) objects. Utilising the concepts of the 3DCDM model in ePlan model and extending LANDXML to support the requirements of 3D cadastres will be the future direction of ePlan and LandXML.

Sixthly, further research is required to validate the model and examine approaches to implementation. Land registries and local councils are among the important users of the model. The 3DCDM model should be validated by various users to assess the quality of the model.

Finally, although data modelling was highlighted as the first step of implementing a successful 3D cadastre, the other technical tolls such as appropriate visualisation platforms are definitely fruitful for implementing the 3D cadastre. Developing platforms to draw, update, and visualise the 3D legal and physical objects of the 3DCDM model will facilitate the implementation of the 3D cadastres and also will change the current process of providing architectural plans and subdivision plans.

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Appendix A- PUBLICATIONS

APPENDIX A: PUBLICATIONS

Aien, A., Kalantari, M., Rajabifard, A., Williamson, I. and Wallace, J., 2013. Towards Integration of 3D Legal and Physical Objects in Cadastral Data Models. Land Use Policy. *Under Review.*

Shojaei, D., Kalantari, M., Bishop, I., Rajabifard, A., and **Aien, A.**, 2013, Visualization Requirements for 3D Cadastral Systems, Computers, Environment and Urban Systems, *accepted.* DOI:10.1016/j.compenvurbsys.2013.04.003.

Aien, A., Kalantari, M., Rajabifard, A., Williamson, I. and Bennett, R., 2013. Utilising Data Modelling to Understand the Structure of 3D Cadastres. Journal of Spatial Science, *accepted.* DOI:10.1080/14498596.2013.801330.

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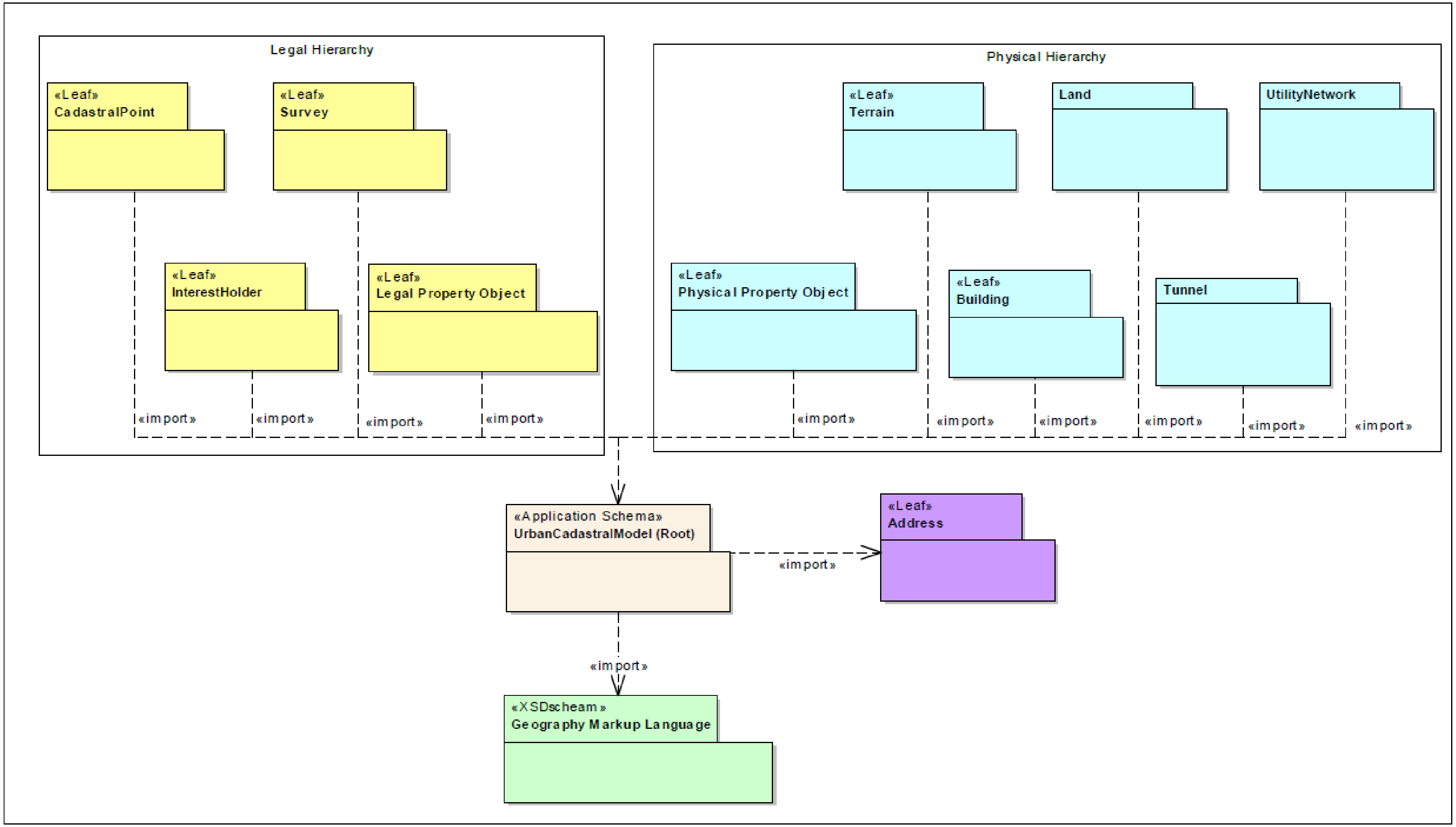
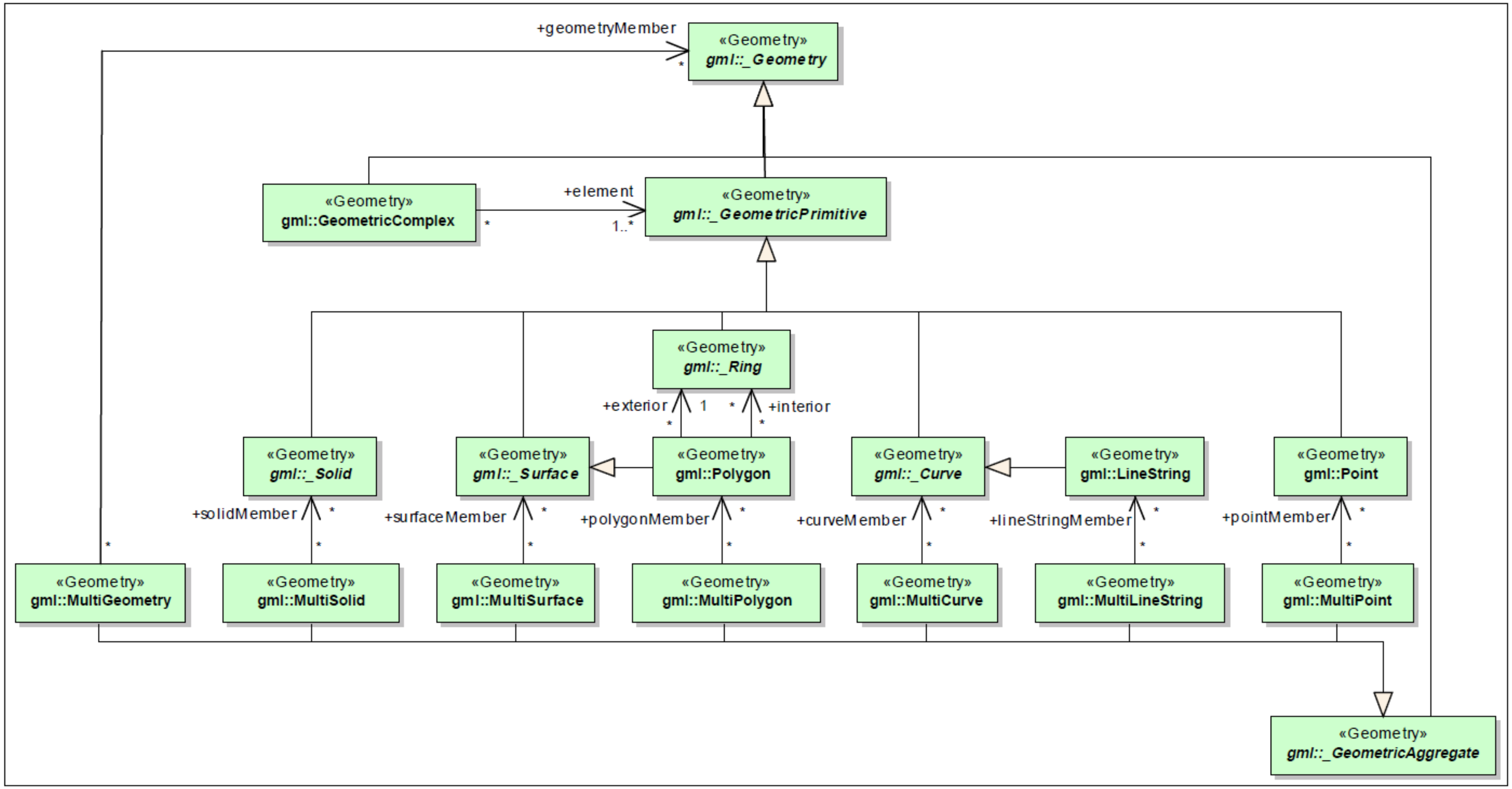
Appendix B- UML DIAGRAM OF THE 3DCDM MODELS

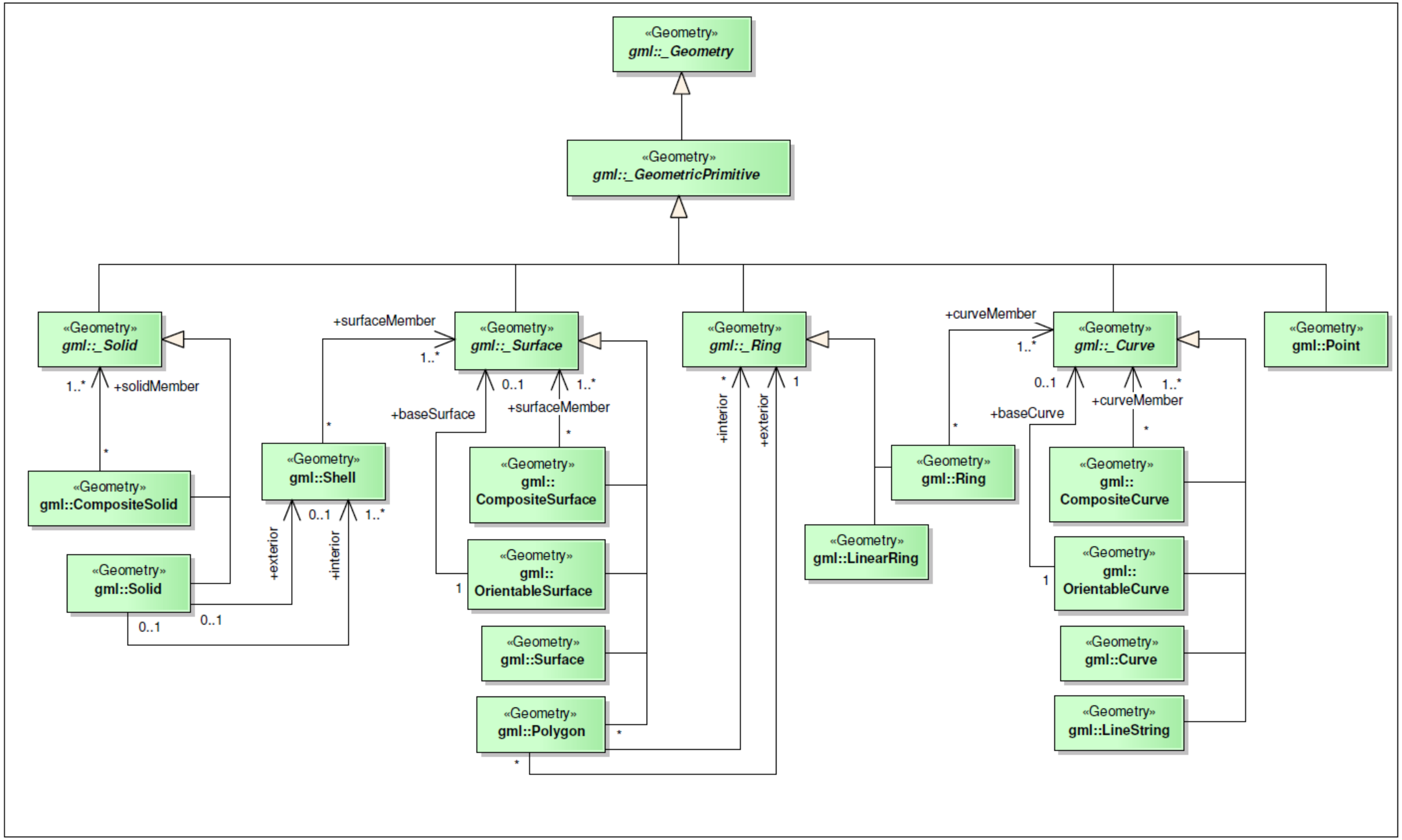
APPENDIX B: UML DIAGRAM OF THE 3DCDM MODELS



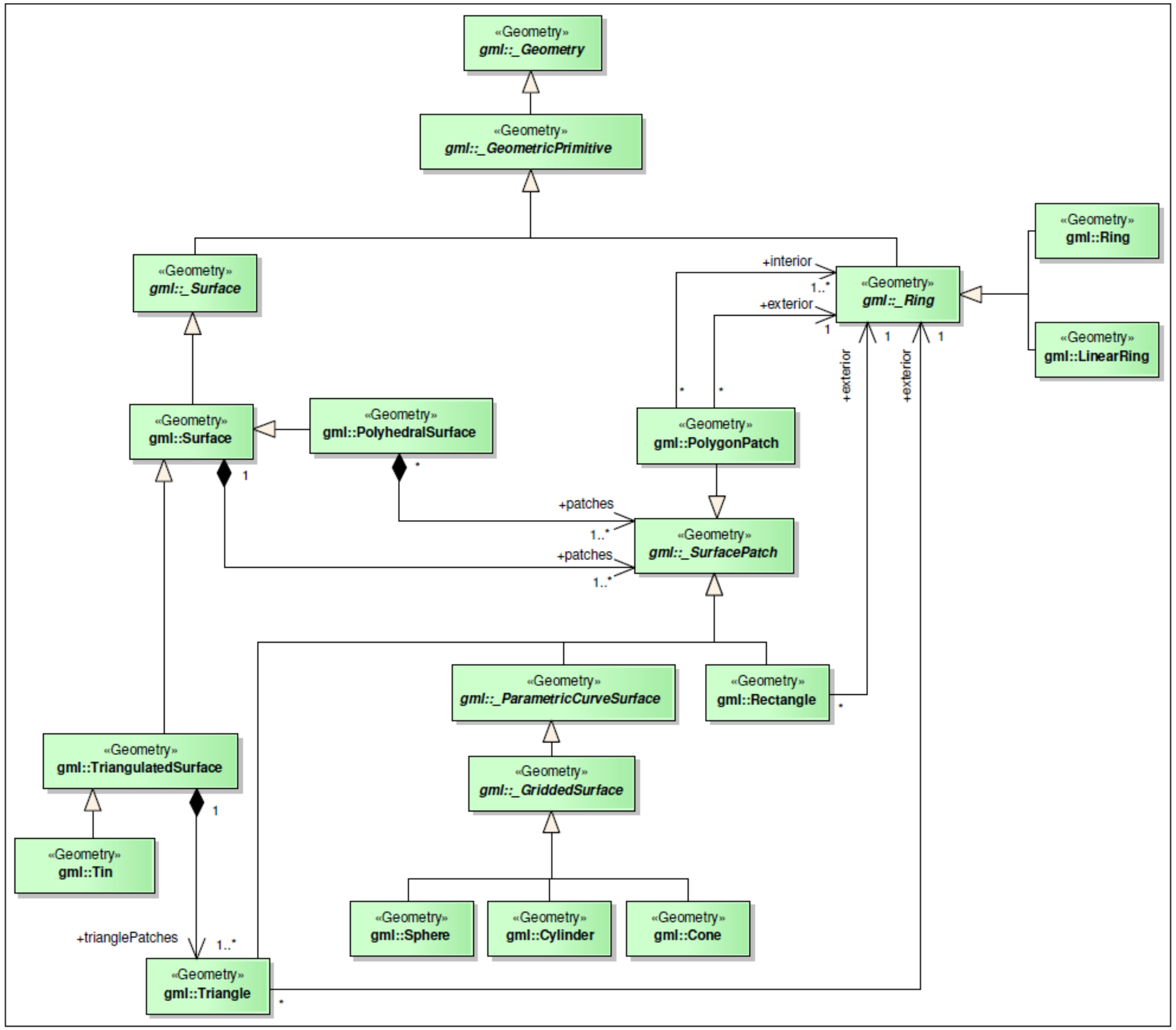
Separate models and hierarchies of the 3DCD



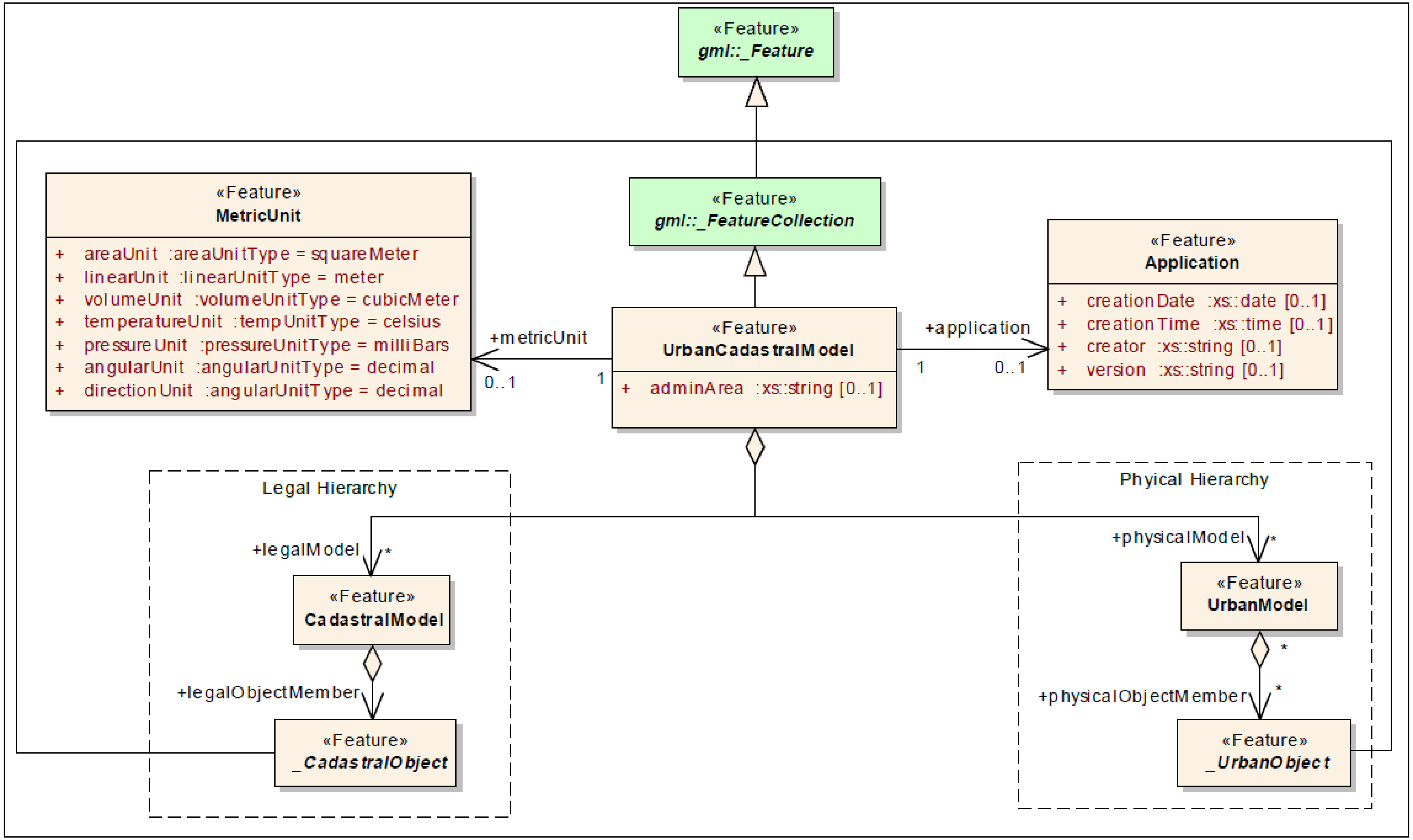
3DCDM Geometry Model - Part 1 (profile of GML3.2.1)



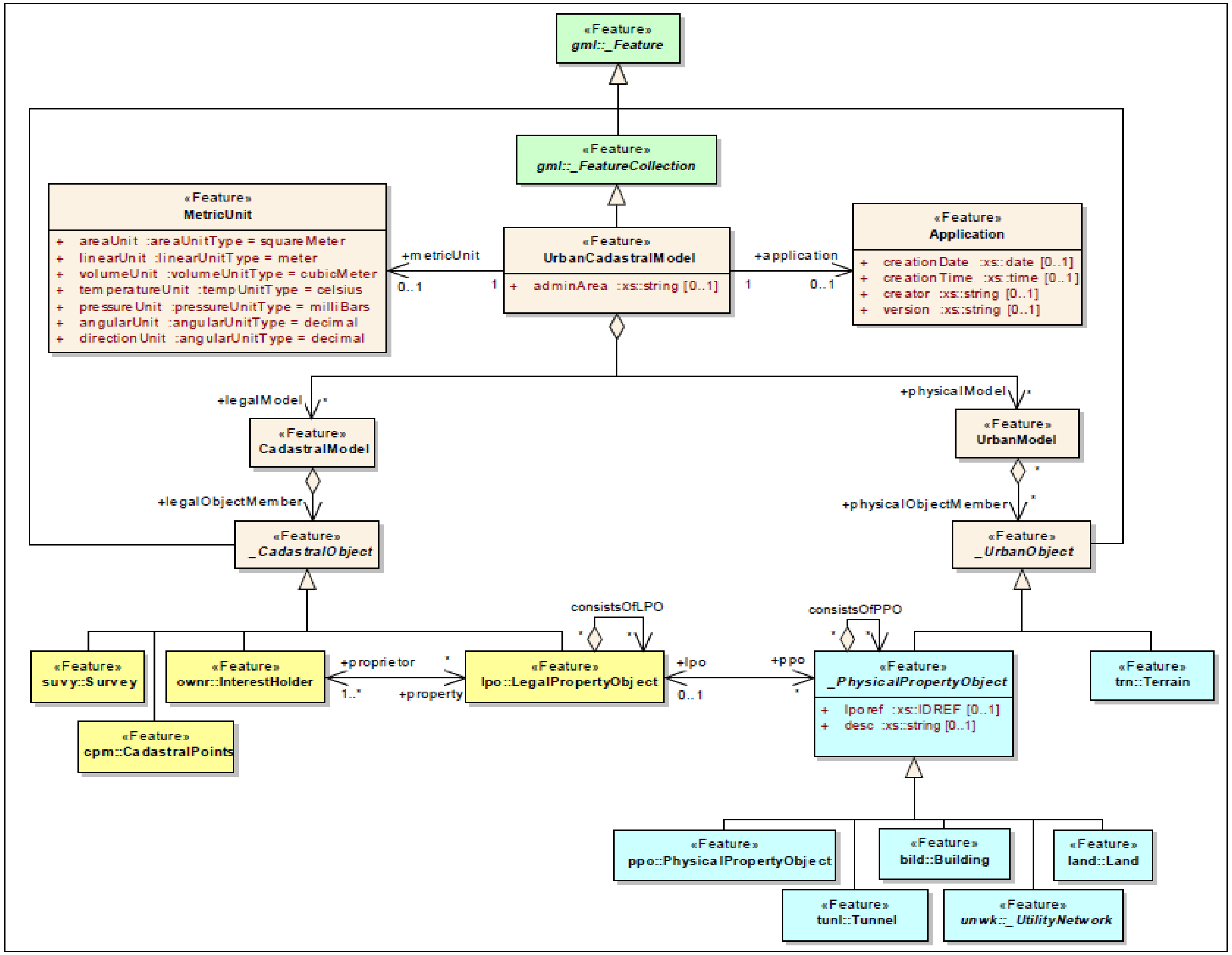
3DCDM Geometry Model - Part 2 (profile of GML3.2.1)



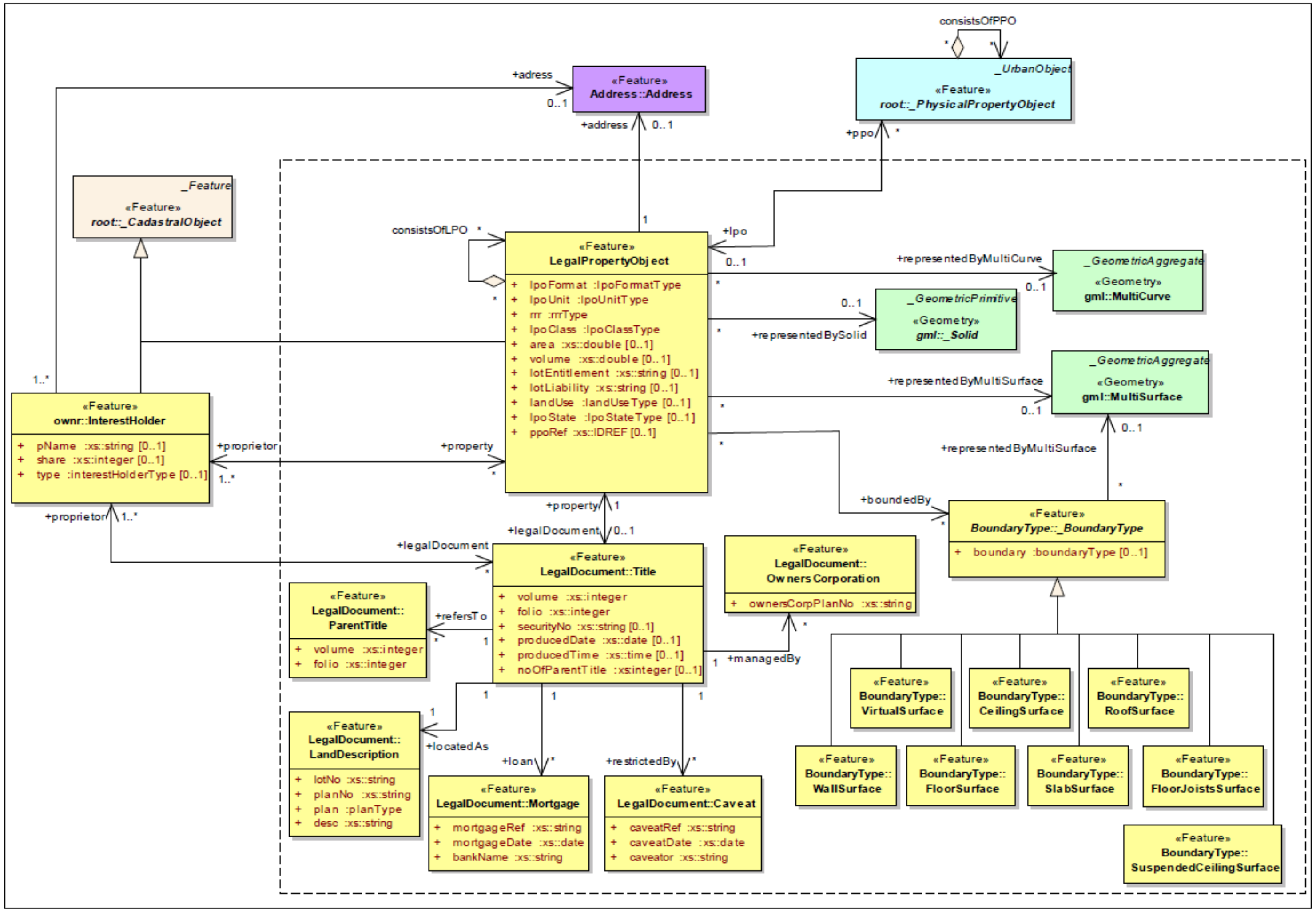
3DCDM Geometry Model – Part 3 (profile of GML3.2.1)



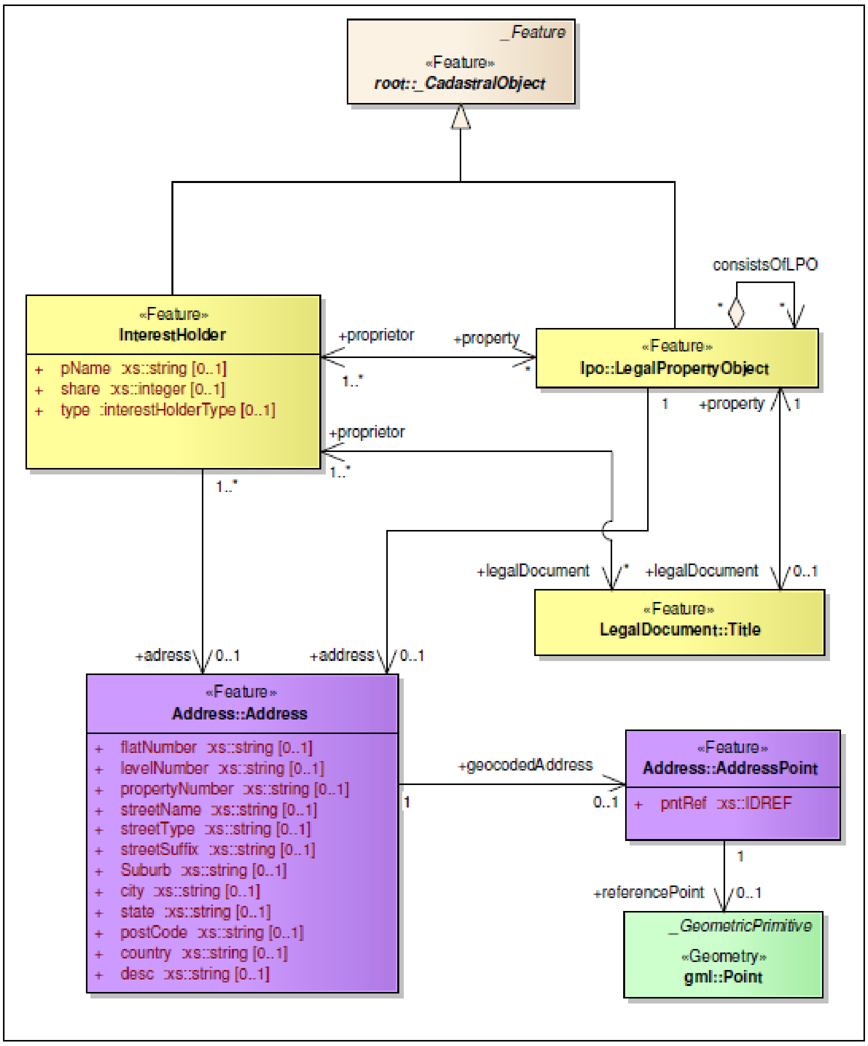
UML diagram of 3DCDM Root model



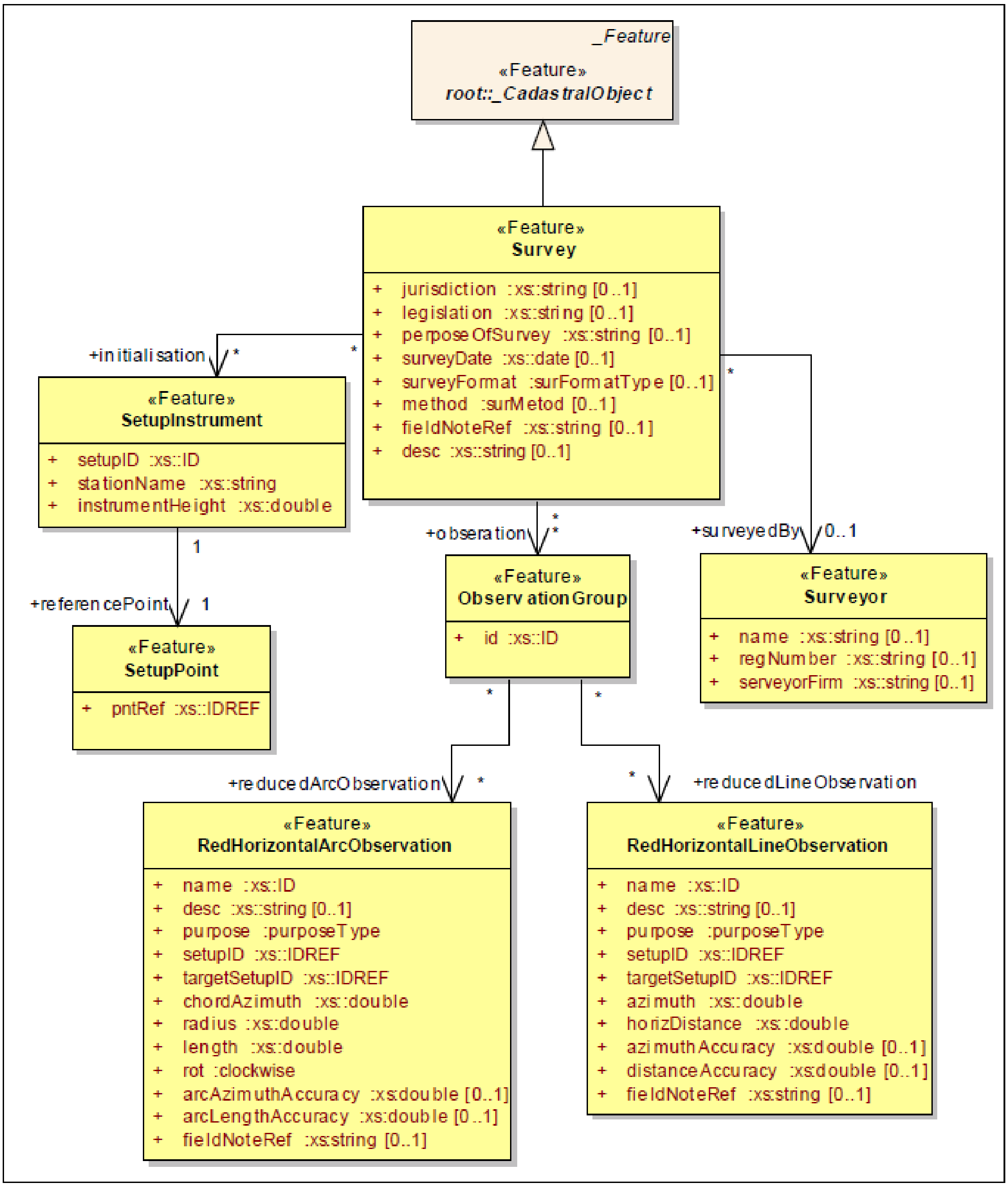
The UML diagram of 3DCDM Root model and the legal and physical model subclasses.



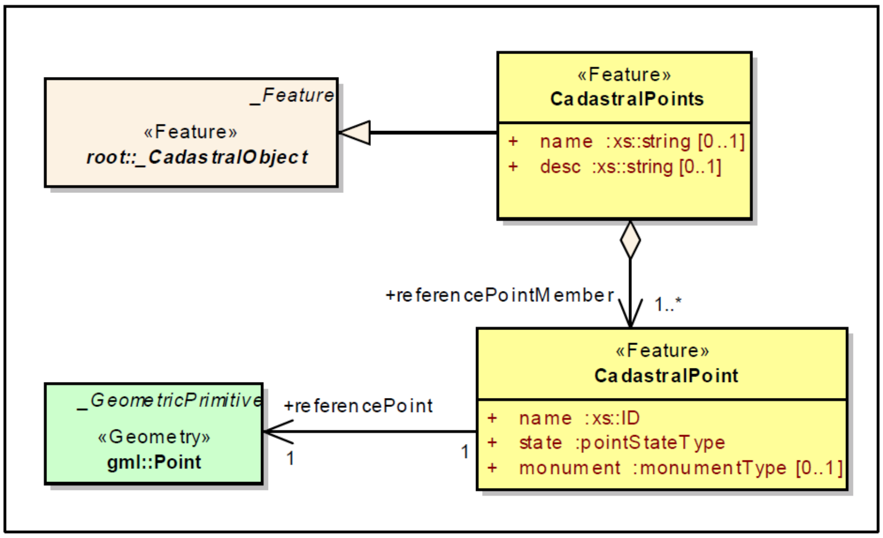
The UML diagram of 3DCDM LegalPropertyObject model.



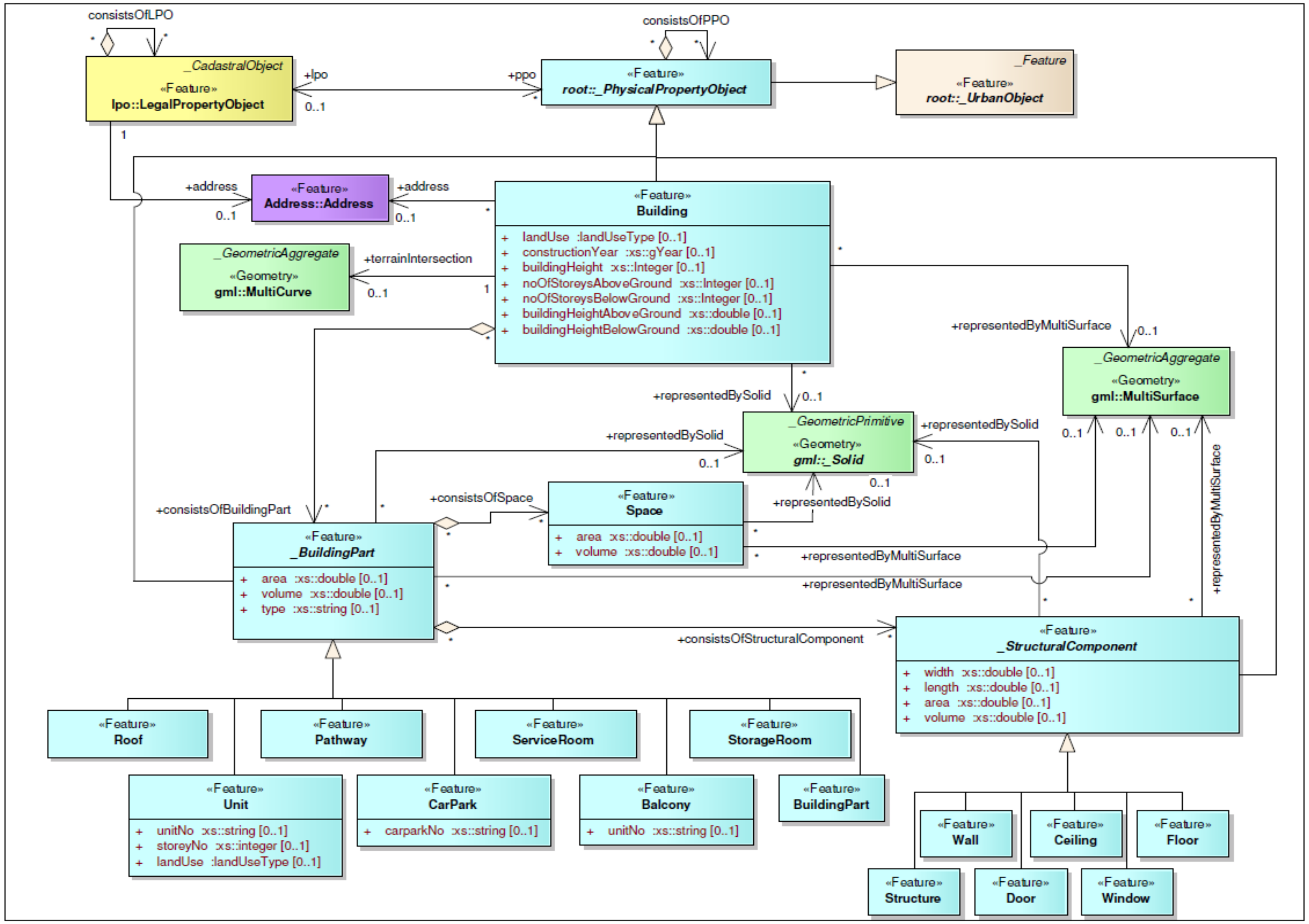
The UML diagram of 3DCDM InterestHolder model.



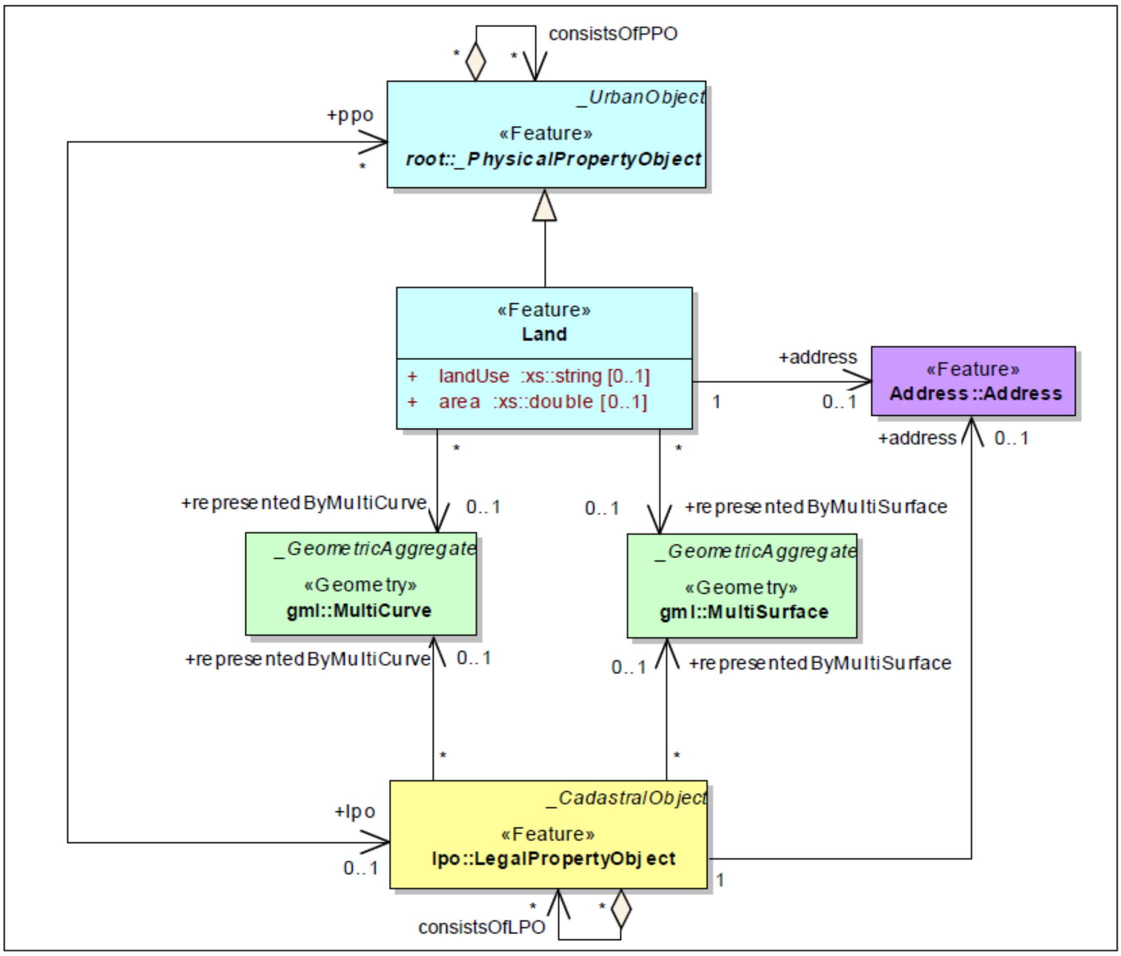
The UML diagram of 3DCDM Survey model.



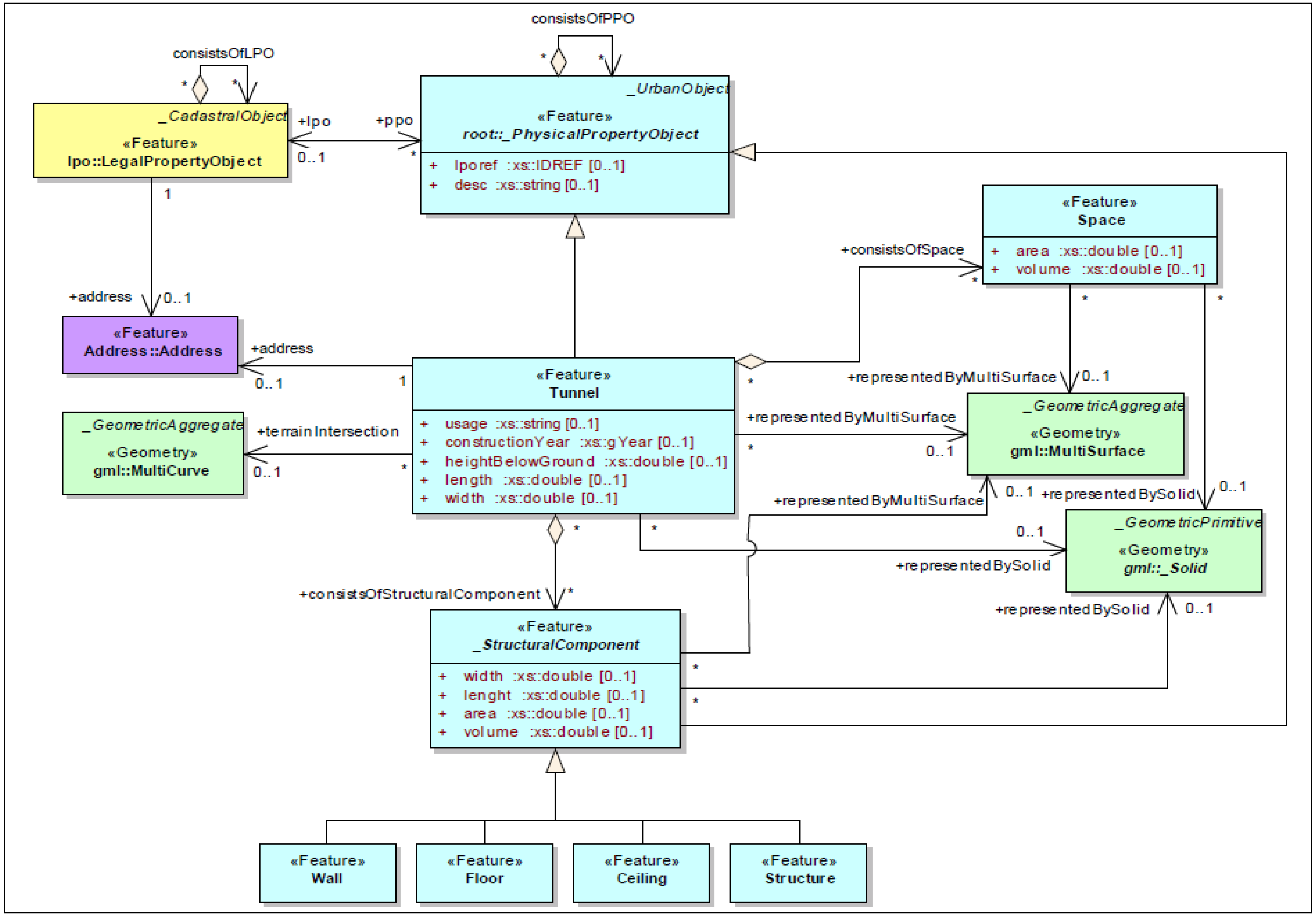
The UML diagram of 3DCDM CadastralPoints model.



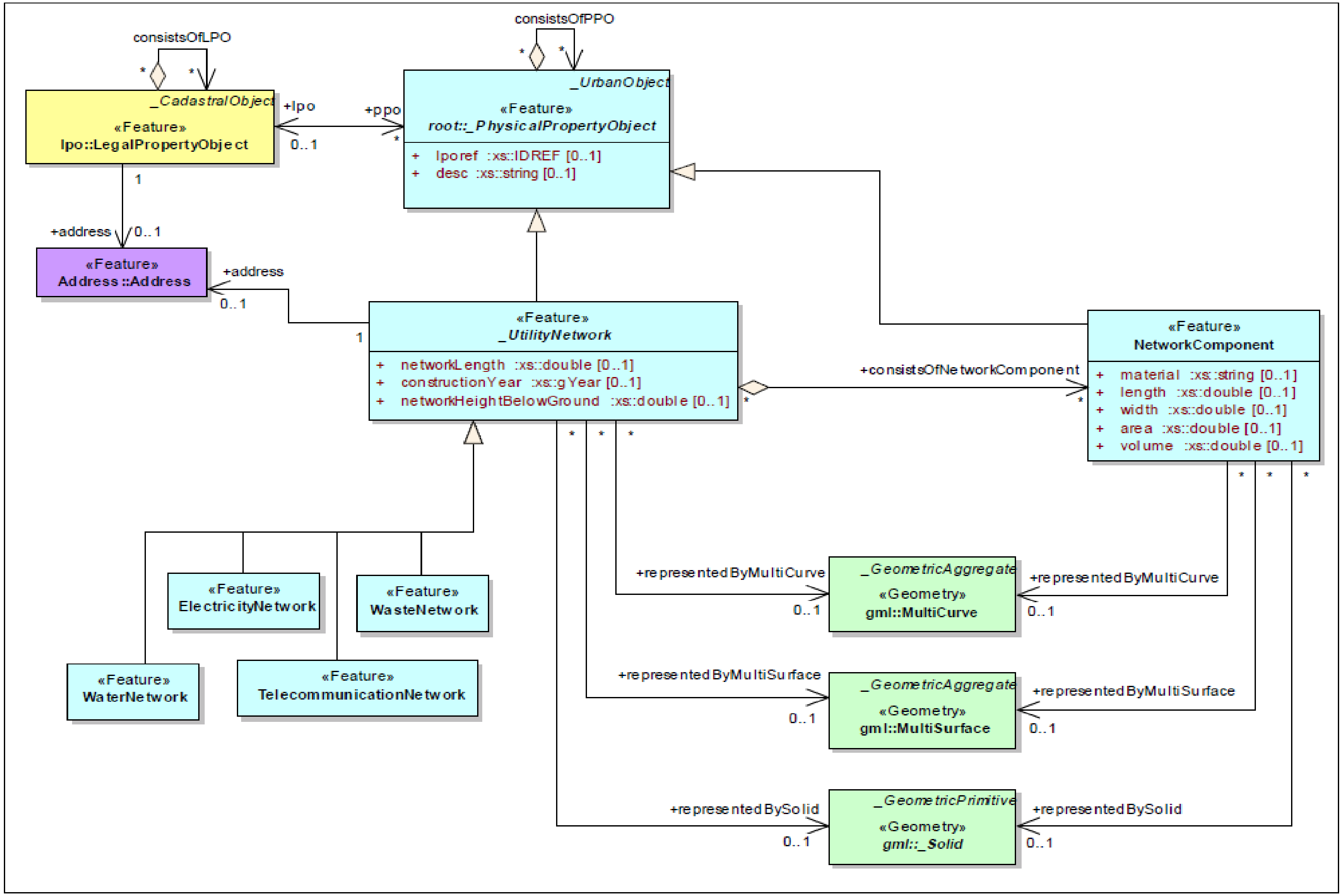
The UML diagram of 3DCDM Building model.



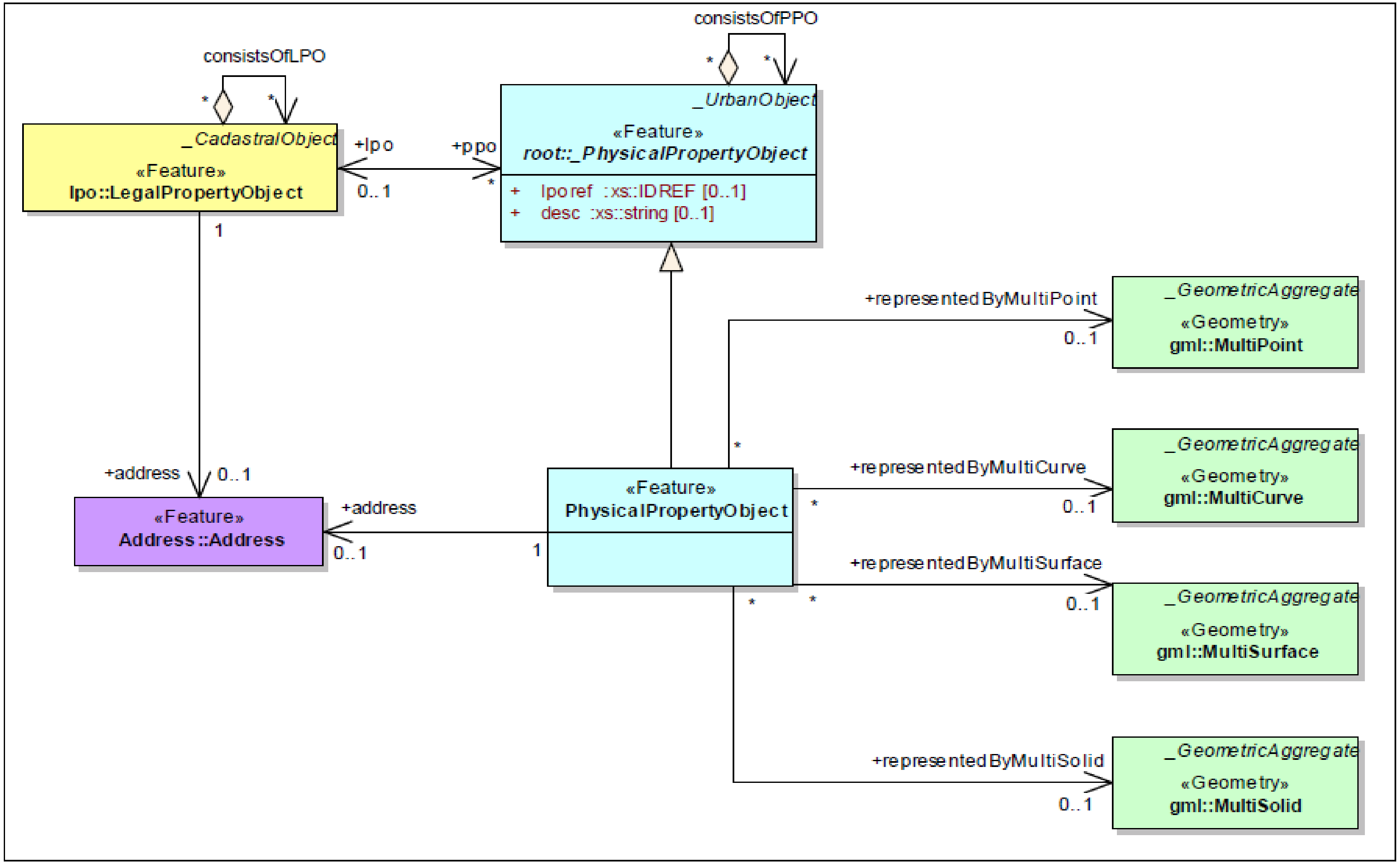
The UML diagram of 3DCDM Land model.



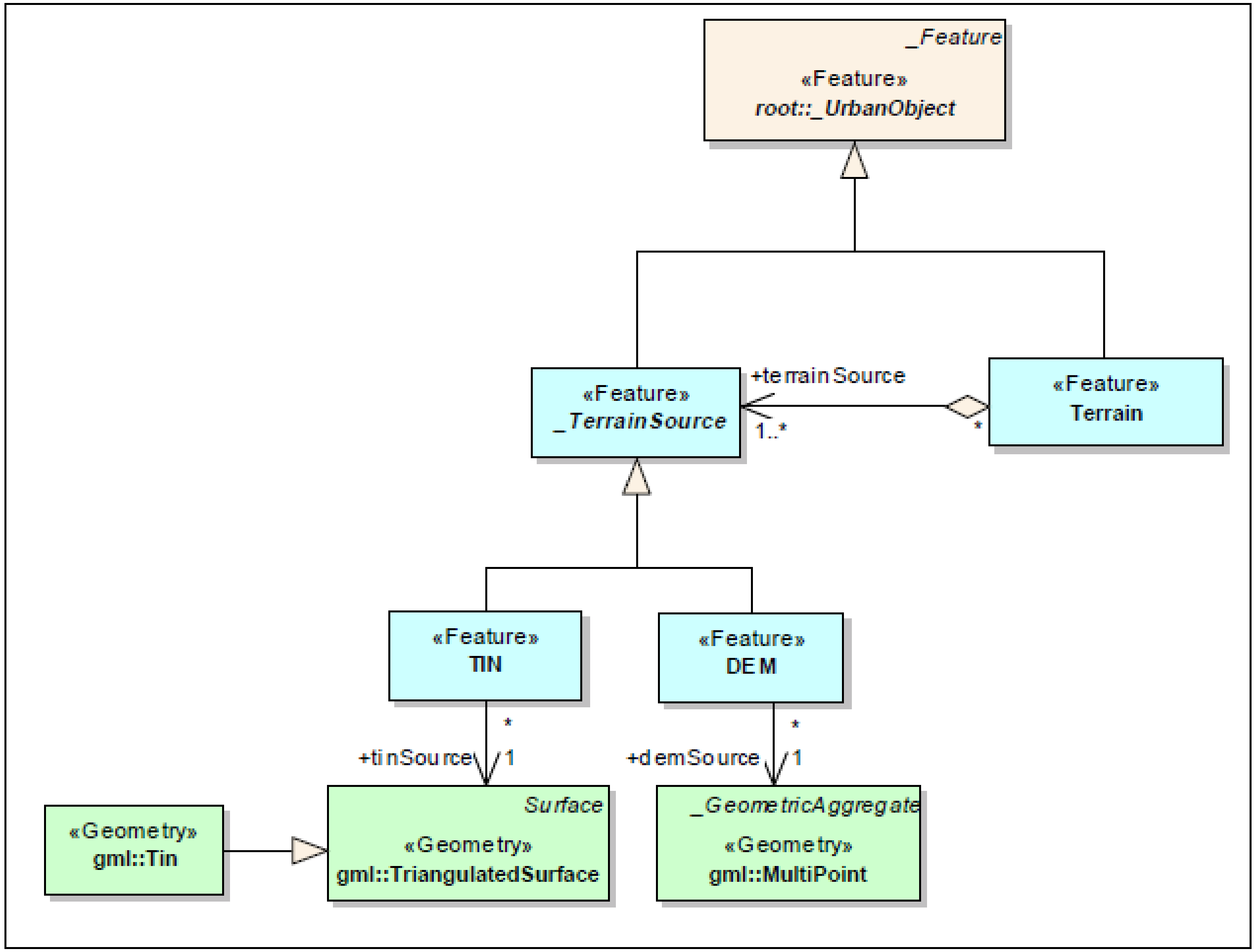
The UML diagram of 3DCDM Tunnel model.



The UML diagram of 3DCDM UtilityNetwork model.



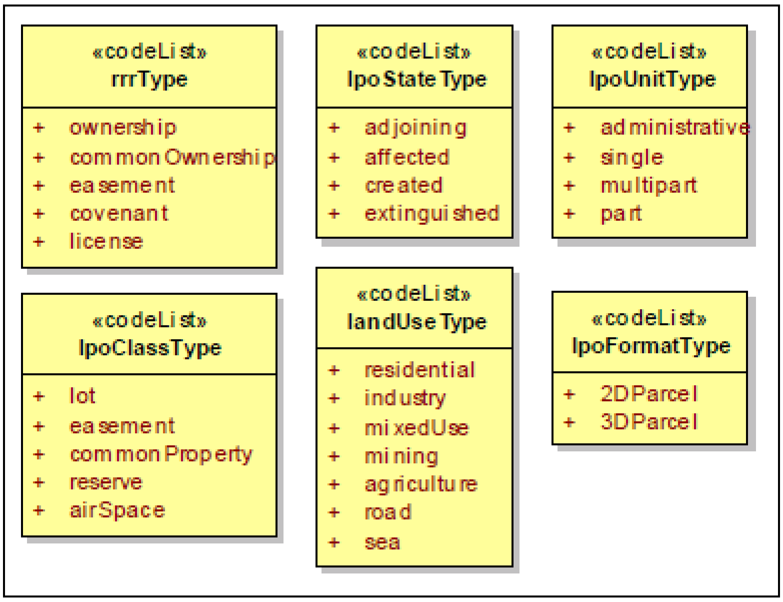
The UML diagram of 3DCDM PhysicalPropertyObject model.



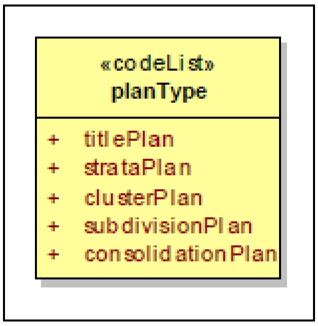
The UML diagram of 3DCDM terrain model.

Appendix C- CODE LISTS OF THE 3DCDM

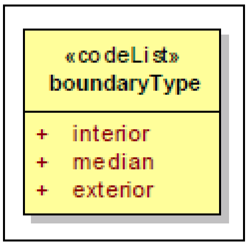
APPENDIX B: CODE LISTS OF THE 3DCDM



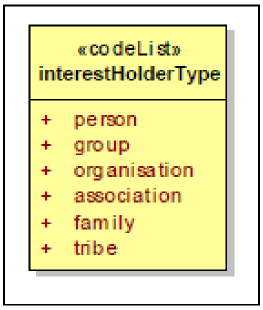
The Code lists for the LegalPropertyObject class



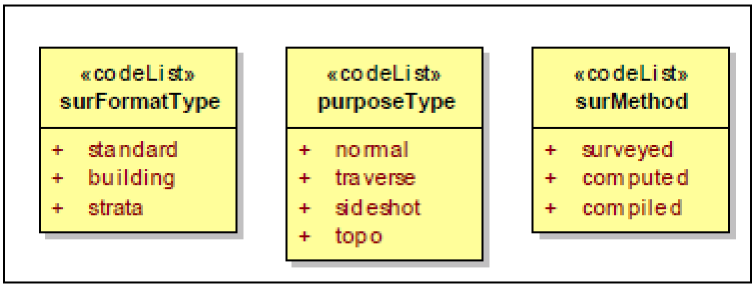
The Code list for the LandDescription



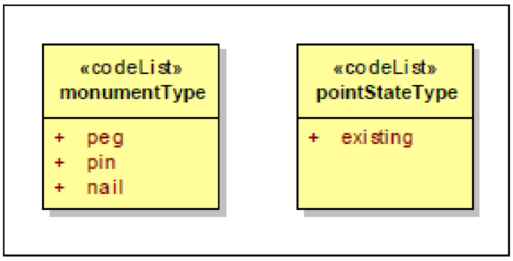
The Code list for the BoundaryType



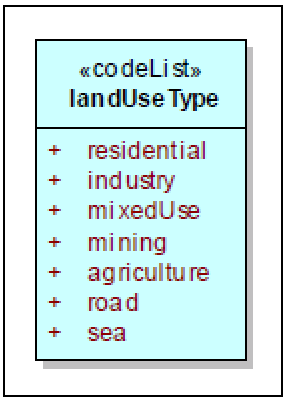
The Code list for the InterestHolder



The Code list for the Survey



The Code list for the CadastralPoints model



The Code list for the Building model

Appendix D- XML SCHEMAS OF THE 3DCDM

APPENDIX D: XML SCHEMAS OF THE 3DCDM

D.1 XML Schema of 3DCDM Root Model

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- 3DCDM Version No. 1.0, December 2012 -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
   xmlns:xs="http://www.w3.org/2001/XMLSchema"
   xmlns:gml="http://www.opengis.net/gml/3.2"
   xmlns="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
   xmlns:lpo="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
   targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
   elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
<xs:annotation>
      <xs:documentation>
         All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University
         of Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
      </xs:documentation>
   </xs:annotation>
   <xs:import
      namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
   <xs:import
      namespace="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
      schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/LegalPropertyObject.xsd"/>
<!-- ============================================================================ -->
<xs:element name="UrabnCadastralModel" type="urabnCadastralModelType"
substitutionGroup="gml:AbstractFeatureCollection"/>
<!-- ============================================================================ -->
   <xs:complexType name="urabnCadastralModelType">
      <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>
<!-- ============================================================================ -->
   <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>
```

```
<!-- ========================================================================== -->
  <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>
<!-- ========================================================================== -->
  <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>
<!-- ========================================================================== -->
  <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"/>
```

```xml
        </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>
<!-- =================================================================================== -->
    <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>
<!-- =================================================================================== -->
<!-- =================================================================================== -->
    <xs:simpleType name="direction">
      <xs:annotation>
        <xs:documentation>Assume 0 degrees = north
      </xs:documentation>
      </xs:annotation>
      <xs:restriction base="xs:double"/>
    </xs:simpleType>
    <xs:simpleType name="clockwise">
      <xs:restriction base="xs:string">
        <xs:enumeration value="cw"/>
        <xs:enumeration value="ccw"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="areaUnitType">
      <xs:restriction base="xs:string">
```

```xml
            <xs:enumeration value="squareMeter"/>
        </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="linearUnitType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="meter"/>
        </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="pressureUnitType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="milliBars"/>
        </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="tempUnitType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="celsius"/>
        </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="volumeUnitType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="cubicMeter"/>
        </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="angularUnitType">
        <xs:annotation>
            <xs:documentation>Angular values expressed in "decimal dd.mm.ss" units have the numeric format "45.3025" representing
            45 degrees 30 minutes and 25 seconds. Both the minutes and seconds must be two characters with a numeric range from 00
            to 60.
            </xs:documentation>
        </xs:annotation>
        <xs:restriction base="xs:string">
            <xs:enumeration value="decimal dd.mm.ss"/>
        </xs:restriction>
    </xs:simpleType>
<!-- =========================================================================== -->
</xs:schema>
```

D.2 XML Schema for 3DCDM LegalPropertyObject Model

```
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:ownr="http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
      All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University
      of Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/InterestHolder.xsd"/>
<!-- ============================================================================ -->
  <xs:element name="LegalPropertyObject" type="LPOType" substitutionGroup="root:_CadastralObject"/>
<!-- ============================================================================ -->
  <xs:complexType name="LPOType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of legal property
objects.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0"/>
          <xs:element name="proprietor" type="proprietorType" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="legalDocument" type="legalDocumentType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="boundedBy" type="BoundarySurfaceType" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="ppo" type="root:AbstractPhysicalPropertyObjectType" minOccurs="0"
          maxOccurs="unbounded"/>
          <xs:element name="consistsOfLPO" type="consistsOfLPOType" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="name" type="xs:string" use="optional"/>
        <xs:attribute name="lpoFormat" type="lpoFormatType" use="required"/>
        <xs:attribute name="lpoUnit" type="lpoUnitType" use="required"/>
        <xs:attribute name="rrr" type="rrrType" use="required"/>
        <xs:attribute name="lpoClass" type="lpoClassType" use="required"/>
        <xs:attribute name="area" type="xs:double" use="optional"/>
        <xs:attribute name="volume" type="xs:double" use="optional"/>
        <xs:attribute name="lotEntitlement" type="xs:string" use="optional"/>
        <xs:attribute name="lotLiability" type="xs:string" use="optional"/>
        <xs:attribute name="landUse" type="landUseType" use="optional"/>
        <xs:attribute name="lpoState" type="lpoStateType" use="required"/>
        <xs:attribute name="ppoRef" type="xs:IDREF" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:complexType name="consistsOfLPOType">
    <xs:annotation>
      <xs:documentation>Type describing the aggregation of physical property objects.</xs:documentation>
```

```xml
        </xs:annotation>
        <xs:sequence minOccurs="0">
            <xs:element ref="LegalPropertyObject"/>
        </xs:sequence>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="proprietorType">
        <xs:annotation>
            <xs:documentation>Type describing the owner.</xs:documentation>
        </xs:annotation>
        <xs:sequence minOccurs="0">
            <xs:element ref="ownr:InterestHolder"/>
        </xs:sequence>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="legalDocumentType">
        <xs:sequence>
            <xs:element ref="Title"/>
        </xs:sequence>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:element name="Title" type="titleType"/>
<!-- ================================================================================ -->
    <xs:complexType name="titleType">
        <xs:annotation>
            <xs:documentation>Type describing the title element.</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="locatedAs" type="planDescType" minOccurs="0"/>
            <xs:element name="refersTo" type="parentType" minOccurs="0"/>
            <xs:element name="loan" type="loanType" minOccurs="0"/>
            <xs:element name="restrictedBy" type="encumbranceType" minOccurs="0"/>
            <xs:element name="managedBy" type="managementType" minOccurs="0"/>
            <xs:element name="property" type="LPOType" minOccurs="0" maxOccurs="1"/>
        </xs:sequence>
        <xs:attribute name="volume" type="nonBlankString" use="required"/>
        <xs:attribute name="folio" type="nonBlankString" use="required"/>
        <xs:attribute name="securityNo" type="xs:string" use="optional"/>
        <xs:attribute name="producedDate" type="xs:date" use="optional"/>
        <xs:attribute name="producedTime" type="xs:time" use="optional"/>
        <xs:attribute name="noOfParentTitle" type="xs:integer" use="optional"/>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="planDescType">
        <xs:sequence>
            <xs:element name="LandDescription" type="landDescriptionType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="landDescriptionType">
        <xs:annotation>
            <xs:documentation>Type describing the land discription of the title.</xs:documentation>
        </xs:annotation>
        <xs:attribute name="lotNo" type="nonBlankString" use="required"/>
        <xs:attribute name="planNo" type="nonBlankString" use="required"/>
        <xs:attribute name="plan" type="planType" use="required"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="parentType">
        <xs:sequence>
            <xs:element name="ParentTitle" type="parentTitleType" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="parentTitleType">
        <xs:annotation>
            <xs:documentation>Type describing the parent title element.</xs:documentation>
        </xs:annotation>
        <xs:attribute name="volume" type="nonBlankString" use="required"/>
        <xs:attribute name="folio" type="nonBlankString" use="required"/>
    </xs:complexType>
```

```xml
<!-- =============================================================================== -->
  <xs:complexType name="loanType">
    <xs:sequence>
      <xs:element name="Mortgage" type="mortgageType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="mortgageType">
    <xs:annotation>
      <xs:documentation>Type describing the mortgage element.</xs:documentation>
    </xs:annotation>
    <xs:attribute name="mortgageRef" type="nonBlankString" use="required"/>
    <xs:attribute name="mortgageType" type="xs:date" use="required"/>
    <xs:attribute name="bankName" type="nonBlankString" use="required"/>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="encumbranceType">
    <xs:sequence>
      <xs:element name="Caveat" type="caveatType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="caveatType">
    <xs:annotation>
      <xs:documentation>Type describing the caveat element.</xs:documentation>
    </xs:annotation>
    <xs:attribute name="caveatRef" type="nonBlankString" use="required"/>
    <xs:attribute name="caveatDate" type="xs:date" use="required"/>
    <xs:attribute name="caveator" type="nonBlankString" use="required"/>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="managementType">
    <xs:sequence>
      <xs:element name="OwnersCorporations" type="ownersCorporationsType" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="ownersCorporationsType">
    <xs:annotation>
      <xs:documentation>Type describing the owners corporations element.</xs:documentation>
    </xs:annotation>
    <xs:attribute name="ownersCorpPlanNo" type="xs:string" use="required"/>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="addressType">
    <xs:sequence>
      <xs:element name="Address" type="addreType"/>
    </xs:sequence>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="addreType">
    <xs:annotation>
      <xs:documentation>Type describing the address element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
    <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
    <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
    <xs:attribute name="streetName" type="xs:string" use="optional"/>
    <xs:attribute name="streetType" type="xs:string" use="optional"/>
    <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
    <xs:attribute name="Suburb" type="xs:string" use="optional"/>
    <xs:attribute name="city" type="xs:string" use="optional"/>
    <xs:attribute name="state" type="xs:string" use="optional"/>
    <xs:attribute name="postCode" type="xs:string" use="optional"/>
    <xs:attribute name="country" type="xs:string" use="optional"/>
    <xs:attribute name="desc" type="xs:string" use="optional"/>
  </xs:complexType>
<!-- =============================================================================== -->
  <xs:complexType name="geocodedAddressType">
```

```
    <xs:sequence>
      <xs:element name="AddressPoint" type="addressPointType"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="addressPointType">
    <xs:annotation>
      <xs:documentation>Type describing the geocoded address element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="referencePoint" type="gml:PointPropertyType"/>
    </xs:sequence>
    <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="BoundarySurfaceType">
    <xs:annotation>
      <xs:documentation>Comment describing BoundarySurfaceType </xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="_BoundaryType"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="_BoundaryType" type="AbstractBoundaryType" abstract="true"/>
<!-- ================================================================================ -->
  <xs:complexType name="AbstractBoundaryType" abstract="true">
    <xs:annotation>
      <xs:documentation>Comment describing _BoundaryType</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0" maxOccurs="1"/>
    </xs:sequence>
    <xs:attribute name="boundary" type="boundaryType" use="optional"/>
    <xs:attribute name="desc" type="xs:string" use="optional"/>
  </xs:complexType>
<!-- ================================================================================ -->
<xs:element name="VirtualSurface" type=" VirtualSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ================================================================================ -->
  <xs:complexType name=" VirtualSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="WallSurface" type="WallSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ================================================================================ -->
  <xs:complexType name="WallSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="FloorSurface" type="FloorSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ================================================================================ -->
  <xs:complexType name="FloorSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="CeilingSurface" type="CeilingSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ================================================================================ -->
  <xs:complexType name="CeilingSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="RoofSurface" type="RoofSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ================================================================================ -->
  <xs:complexType name="RoofSurfaceType">
```

```xml
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:element name="SlabSurface" type="SlabSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ============================================================================ -->
  <xs:complexType name="SlabSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:element name="SuspendedCeilingSurface" type="SuspendedCeilingSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ============================================================================ -->
  <xs:complexType name="SuspendedCeilingSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:element name="FloorJoistsSurface" type="FloorJoistsSurfaceType" substitutionGroup="_BoundaryType"/>
<!-- ============================================================================ -->
  <xs:complexType name="FloorJoistsSurfaceType">
    <xs:complexContent>
      <xs:extension base="AbstractBoundaryType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================ -->
<!-- ============================================================================ -->
  <xs:simpleType name="nonBlankString">
    <xs:restriction base="xs:string">
      <xs:minLength value="1"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ============================================================================ -->
  <xs:simpleType name="lpoStateType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="adjoining"/>
      <xs:enumeration value="affected"/>
      <xs:enumeration value="created"/>
      <xs:enumeration value="extinguished"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ============================================================================ -->
  <xs:simpleType name="planType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="titlePlan"/>
      <xs:enumeration value="strataPlan"/>
      <xs:enumeration value="clusterPlan"/>
      <xs:enumeration value="SubdivisionPlan"/>
      <xs:enumeration value="consolidationPlan"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ============================================================================ -->
  <xs:simpleType name="lpoFormatType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="2DParcel"/>
      <xs:enumeration value="3DParcel"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ============================================================================ -->
  <xs:simpleType name="lpoUnitType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="administrative"/>
      <xs:enumeration value="single"/>
      <xs:enumeration value="multipart"/>
      <xs:enumeration value="part"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ============================================================================ -->
  <xs:simpleType name="rrrType">
```

```
    <xs:restriction base="xs:string">
      <xs:enumeration value="ownership"/>
      <xs:enumeration value="commonOwnership"/>
      <xs:enumeration value="easement"/>
      <xs:enumeration value="covenant"/>
      <xs:enumeration value="license"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ================================================================================ -->
  <xs:simpleType name="lpoClassType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="lot"/>
      <xs:enumeration value="easement"/>
      <xs:enumeration value="commonProperty"/>
      <xs:enumeration value="reserve"/>
      <xs:enumeration value="airSpace"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ================================================================================ -->
  <xs:simpleType name="landUseType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="residential"/>
      <xs:enumeration value="industry"/>
      <xs:enumeration value="mixedUse"/>
      <xs:enumeration value="mining"/>
      <xs:enumeration value="agriculture"/>
      <xs:enumeration value="road"/>
      <xs:enumeration value="sea"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ================================================================================ -->
  <xs:simpleType name="boundaryType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="interior"/>
      <xs:enumeration value="median"/>
      <xs:enumeration value="exterior"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ================================================================================ -->
</xs:schema>
```

D.3 XML Schema for 3DCDM InterestHolder Model

```xml
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
   xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:lpo="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
      All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University
      of Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/LegalPropertyObject.xsd"/>
<!-- ============================================================================ -->
  <xs:element name="InterestHolder" type="interestHolderType" substitutionGroup="root:_CadastralObject"/>
<!-- ============================================================================ -->
  <xs:complexType name="interestHolderType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of proprietors.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation>  </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="legalDocument" type="legalDocumentType" minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="property" type="propertyType" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="pName" type="xs:string" use="optional"/>
        <xs:attribute name="share" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="type" type="ownerType" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:complexType name="legalDocumentType">
    <xs:annotation>
      <xs:documentation>Type describing the title element.</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="lpo:Title"/>
    </xs:sequence>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:complexType name="propertyType">
    <xs:annotation>
      <xs:documentation>Type describing Legal Property Object.</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="lpo:LegalPropertyObject"/>
    </xs:sequence>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:complexType name="addressType">
    <xs:sequence>
      <xs:element name="Address" type="addreType"/>
    </xs:sequence>
```

```xml
  </xs:complexType>
<!-- ============================================================================== -->
  <xs:complexType name="addreType">
    <xs:annotation>
      <xs:documentation>Type describing the address element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
    <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
    <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
    <xs:attribute name="streetName" type="xs:string" use="optional"/>
    <xs:attribute name="streetType" type="xs:string" use="optional"/>
    <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
    <xs:attribute name="Suburb" type="xs:string" use="optional"/>
    <xs:attribute name="city" type="xs:string" use="optional"/>
    <xs:attribute name="state" type="xs:string" use="optional"/>
    <xs:attribute name="postCode" type="xs:string" use="optional"/>
    <xs:attribute name="country" type="xs:string" use="optional"/>
    <xs:attribute name="desc" type="xs:string" use="optional"/>
  </xs:complexType>
<!-- ============================================================================== -->
  <xs:complexType name="geocodedAddressType">
    <xs:sequence>
      <xs:element name="AddressPoint" type="addressPointType"/>
    </xs:sequence>
  </xs:complexType>
<!-- ============================================================================== -->
  <xs:complexType name="addressPointType">
    <xs:annotation>
      <xs:documentation>Type describing the geocoded address element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="referencePoint" type="gml:PointPropertyType"/>
    </xs:sequence>
    <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
  </xs:complexType>
<!-- ============================================================================== -->
<!-- ============================================================================== -->
  <xs:simpleType name="ownerType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="person"/>
      <xs:enumeration value="group"/>
      <xs:enumeration value="organisation"/>
      <xs:enumeration value="association"/>
      <xs:enumeration value="family"/>
      <xs:enumeration value="tribe"/>
    </xs:restriction>
  </xs:simpleType>
<!-- ============================================================================== -->
</xs:schema>
```

D.4 XML Schema for 3DCDM Survey Model

```xml
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/survey/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
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      of Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- ============================================================================ -->
  <xs:element name="Survey" type="surveyType" substitutionGroup="root:_CadastralObject"/>
<!-- ============================================================================ -->
  <xs:complexType name="surveyType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of surveying element.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation/>
          </xs:annotation>
          <xs:element name="surveyedBy" type="surveyedByType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="initialisation" type="initialisationType" minOccurs="0"/>
          <xs:element name="observation" type="observationType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="jurisdiction" type="xs:string" use="optional"/>
        <xs:attribute name="legislation" type="xs:string" use="optional"/>
        <xs:attribute name="purposeofSurvey" type="xs:string" use="optional"/>
        <xs:attribute name="surveyDate" type="xs:date" use="optional"/>
        <xs:attribute name="surveyFormat" type="surFormatType" use="optional"/>
        <xs:attribute name="method" type="surMethod" use="optional"/>
        <xs:attribute name="fieldNoteRef" type="xs:string" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:complexType name="surveyedByType">
    <xs:annotation>
      <xs:documentation>Comment describing surveyedByType</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="surveyor" type="surveyorType" minOccurs="0" maxOccurs="1"/>
    </xs:sequence>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:complexType name="surveyorType">
    <xs:annotation>
      <xs:documentation>Comment describing surveyorType</xs:documentation>
    </xs:annotation>
    <xs:attribute name="name" type="xs:string" use="optional"/>
    <xs:attribute name="regNumber" type="xs:string" use="optional"/>
    <xs:attribute name="surveyorFirm" type="xs:string" use="optional"/>
  </xs:complexType>
<!-- ============================================================================ -->
  <xs:complexType name="initialisationType">
    <xs:annotation>
```

```
        <xs:documentation>Comment describing initialisationType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
        <xs:element name="SetupInstrument" type="setupInstrumentType" minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="setupInstrumentType">
      <xs:annotation>
        <xs:documentation>Comment describing setupInstrumentType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
        <xs:element name="referencePoint" type="referencePointType"/>
      </xs:sequence>
      <xs:attribute name="setupID" type="xs:ID" use="required"/>
      <xs:attribute name="stationName" type="nonBlankString" use="required"/>
      <xs:attribute name="instrumentHeight" type="xs:double" use="required"/>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="referencePointType">
      <xs:annotation>
        <xs:documentation>Comment describing referencePointType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
        <xs:element name="SetupPoint" type="setupPointType"/>
      </xs:sequence>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="setupPointType">
      <xs:annotation>
        <xs:documentation>Comment describing setupPointType</xs:documentation>
      </xs:annotation>
      <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="observationType">
      <xs:annotation>
        <xs:documentation>Comment describing observationType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
        <xs:element name="ObservationGroup" type="observationGroupType" minOccurs="0"/>
      </xs:sequence>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="observationGroupType">
      <xs:annotation>
        <xs:documentation>Comment describing observationGroupType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
        <xs:choice maxOccurs="unbounded">
          <xs:element name="reducedLineObservation" type="reducedLineObservationType" minOccurs="0"/>
          <xs:element name="reducedArcObservation" type="reducedArcObservationType" minOccurs="0"/>
        </xs:choice>
      </xs:sequence>
      <xs:attribute name="id" type="xs:ID" use="required"/>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="reducedLineObservationType">
      <xs:annotation>
        <xs:documentation>Comment describing reducedLineObservationType</xs:documentation>
      </xs:annotation>
      <xs:sequence>
        <xs:element name="RedHorizontalLineObservation" type="redHorizontalLineObservation"/>
      </xs:sequence>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="redHorizontalLineObservation">
      <xs:annotation>
        <xs:documentation>Comment describing redHorizontalLineObservation</xs:documentation>
      </xs:annotation>
      <xs:attribute name="name" type="xs:ID" use="required"/>
      <xs:attribute name="desc" type="nonBlankString" use="optional"/>
```

```
        <xs:attribute name="purpose" type="purposeType" use="required"/>
        <xs:attribute name="setupID" type="xs:IDREF" use="required"/>
        <xs:attribute name="targetSetupID" type="xs:IDREF" use="required"/>
        <xs:attribute name="azimuth" type="xs:double" use="required"/>
        <xs:attribute name="horizDistance" type="xs:double" use="required"/>
        <xs:attribute name="azimuthAccuracy" type="xs:double" use="optional"/>
        <xs:attribute name="distanceAccuracy" type="xs:double" use="optional"/>
        <xs:attribute name="fieldNoteRef" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="reducedArcObservationType">
        <xs:annotation>
            <xs:documentation>Comment describing reducedArcObservationType</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="RedHorizontalArcObservation" type="redHorizontalArcObservationType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ================================================================================ -->
    <xs:complexType name="redHorizontalArcObservationType">
        <xs:annotation>
            <xs:documentation>Comment describing redHorizontalArcObservationType</xs:documentation>
        </xs:annotation>
        <xs:attribute name="name" type="xs:ID" use="required"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
        <xs:attribute name="purpose" type="purposeType" use="required"/>
        <xs:attribute name="setupID" type="xs:IDREF" use="required"/>
        <xs:attribute name="targetSetupID" type="xs:IDREF" use="required"/>
        <xs:attribute name="chordAzimuth" type="xs:double" use="required"/>
        <xs:attribute name="radius" type="xs:double" use="required"/>
        <xs:attribute name="length" type="xs:double" use="required"/>
        <xs:attribute name="rot" type="clockwise" use="required"/>
        <xs:attribute name="arcAzimuthAccuracy" type="xs:double" use="optional"/>
        <xs:attribute name="arcLengthAccuracy" type="xs:double" use="optional"/>
        <xs:attribute name="fieldNoteRef" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- ================================================================================ -->
<!-- ================================================================================ -->
    <xs:simpleType name="nonBlankString">
        <xs:restriction base="xs:string">
            <xs:minLength value="1"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ================================================================================ -->
    <xs:simpleType name="direction">
        <xs:annotation>
            <xs:documentation>Assume 0 degrees = north
        </xs:documentation>
        </xs:annotation>
        <xs:restriction base="xs:double"/>
    </xs:simpleType>
    <xs:simpleType name="clockwise">
        <xs:restriction base="xs:string">
            <xs:enumeration value="cw"/>
            <xs:enumeration value="ccw"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ================================================================================ -->
    <xs:simpleType name="lpoStateType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="adjoining"/>
            <xs:enumeration value="affected"/>
            <xs:enumeration value="created"/>
            <xs:enumeration value="extinguished"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ================================================================================ -->
    <xs:simpleType name="purposeType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="normal"/>
            <xs:enumeration value="traverse"/>
            <xs:enumeration value="sideshot"/>
```

```xml
            <xs:enumeration value="topo"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ================================================================================ -->
    <xs:simpleType name="surFormatType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="standard"/>
            <xs:enumeration value="building"/>
            <xs:enumeration value="strata"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ================================================================================ -->
    <xs:simpleType name="surMethod">
        <xs:restriction base="xs:string">
            <xs:enumeration value="surveyed"/>
            <xs:enumeration value="computed"/>
            <xs:enumeration value="compiled"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ================================================================================ -->
</xs:schema>
```

D.5 XML Schema for 3DCDM CadastralPoints Model

```
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/cadastralpoint/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/cadastralpoint/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
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      of Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- ========================================================================== -->
  <xs:element name="CadastralPoints" type="cadastralPointsType" substitutionGroup="root:_CadastralObject"/>
<!-- ========================================================================== -->
  <xs:complexType name="cadastralPointsType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of cadastral points.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractCadastralObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation/>
          </xs:annotation>
          <xs:element name="referencePointMember" type="referencePointMemberType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="name" type="xs:string" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:complexType name="referencePointMemberType">
    <xs:annotation>
      <xs:documentation>Comment describing referencePointMemberType</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="CadastralPoint" type="cadastralPointType" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:complexType name="cadastralPointType">
    <xs:annotation>
      <xs:documentation>Comment describing cadastralPointType</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="referencePoint" type="gml:PointPropertyType" minOccurs="1"/>
    </xs:sequence>
    <xs:attribute name="name" type="xs:ID" use="required"/>
    <xs:attribute name="state" type="pointStateType" use="required"/>
    <xs:attribute name="monument" type="monumentType" use="optional"/>
  </xs:complexType>
<!-- ========================================================================== -->
<!-- ========================================================================== -->
  <xs:simpleType name="monumentType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="peg"/>
      <xs:enumeration value="pin"/>
      <xs:enumeration value="nail"/>
    </xs:restriction>
```

```
    </xs:simpleType>
<!-- ============================================================================ -->
    <xs:simpleType name="dimensionType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="2D"/>
            <xs:enumeration value="3D"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ============================================================================ -->
    <xs:simpleType name="pointStateType">
        <xs:restriction base="xs:string">
            <xs:enumeration value="existing"/>
        </xs:restriction>
    </xs:simpleType>
<!-- ============================================================================ -->
</xs:schema>
```

D.6 XML Schema for 3DCDM Building Model

```
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/building/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/building/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
    All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University of
    Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- ========================================================================== -->
  <xs:element name="Building" type="BuildingType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ========================================================================== -->
  <xs:complexType name="BuildingType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of buildings.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="terrainIntersection" type="gml:MultiCurvePropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="consistsOfBuildingPart" type="BuildingPartPropertyType" minOccurs="0"
          maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="landUse" type="landUseType" use="optional"/>
        <xs:attribute name="constructionYear" type="xs:gYear" use="optional"/>
        <xs:attribute name="buildingHeight" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="noOfStoreysAboveGround" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="noOfStoreysBelowGround" type="xs:nonNegativeInteger" use="optional"/>
        <xs:attribute name="buildingHeightAboveGround" type="xs:double" use="optional"/>
        <xs:attribute name="buildingHeightBelowGround" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:complexType name="BuildingPartPropertyType">
    <xs:annotation>
      <xs:documentation>Comment describing BuildingPartPropertyType.</xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="_BuildingPart"/>
    </xs:sequence>
  </xs:complexType>
<!-- ========================================================================== -->
  <xs:element name="_BuildingPart" type="AbstractBuildingPartType" abstract="true"
  substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ========================================================================== -->
  <xs:complexType name="AbstractBuildingPartType" abstract="true">
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
```

```xml
            <xs:element name="consistsOfStructuralComponent" type="StructuralComponentPropertyType" minOccurs="0"
            maxOccurs="unbounded"/>
            <xs:element name="consistsOfSpace" type="SpacePropertyType" minOccurs="0"/>
            <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
            <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
            maxOccurs="1"/>
          </xs:sequence>
          <xs:attribute name="area" type="xs:double" use="optional"/>
          <xs:attribute name="volume" type="xs:double" use="optional"/>
          <xs:attribute name="type" type="xs:string" use="optional"/>
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================================== -->
    <xs:complexType name="SpacePropertyType">
      <xs:annotation>
        <xs:documentation>Comment describing SpacePropertyType</xs:documentation>
      </xs:annotation>
      <xs:sequence minOccurs="0">
        <xs:element ref="Space"/>
      </xs:sequence>
    </xs:complexType>
<!-- ====================================================================================== -->
    <xs:element name="Space" type="SpaceType"/>
<!-- ====================================================================================== -->
    <xs:complexType name="SpaceType">
      <xs:annotation>
        <xs:documentation>Comment describing SpacePropertType.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
        <xs:extension base="root:AbstractPhysicalPropertyObjectType">
          <xs:sequence>
            <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
            <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
            maxOccurs="1"/>
          </xs:sequence>
          <xs:attribute name="area" type="xs:double" use="optional"/>
          <xs:attribute name="volume" type="xs:double" use="optional"/>
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================================== -->
    <xs:complexType name="StructuralComponentPropertyType">
      <xs:annotation>
        <xs:documentation>Comment describing StructurePropertyType</xs:documentation>
      </xs:annotation>
      <xs:sequence minOccurs="0">
        <xs:element ref="_StructuralComponent"/>
      </xs:sequence>
    </xs:complexType>
<!-- ====================================================================================== -->
    <xs:element name="_StructuralComponent" type="AbstractStructuralComponentType" abstract="true"
    substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ====================================================================================== -->
    <xs:complexType name="AbstractStructuralComponentType" abstract="true">
      <xs:annotation>
        <xs:documentation>Comment describing AbstractStructuralComponentType</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
        <xs:extension base="root:AbstractPhysicalPropertyObjectType">
          <xs:sequence>
            <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
            <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
            maxOccurs="1"/>
          </xs:sequence>
          <xs:attribute name="width" type="xs:double" use="optional"/>
          <xs:attribute name="length" type="xs:double" use="optional"/>
          <xs:attribute name="area" type="xs:double" use="optional"/>
          <xs:attribute name="volume" type="xs:double" use="optional"/>
        </xs:extension>
      </xs:complexContent>
    </xs:complexType>
```

```xml
<!-- ================================================================================ -->
  <xs:element name="Wall" type="WallType" substitutionGroup="_StructuralComponent"/>
<!-- ================================================================================ -->
  <xs:complexType name="WallType">
    <xs:annotation>
      <xs:documentation>Comment describing WallType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="Floor" type="FloorType" substitutionGroup="_StructuralComponent"/>
<!-- ================================================================================ -->
  <xs:complexType name="FloorType">
    <xs:annotation>
      <xs:documentation>Comment describing FloorType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="Ceiling" type="CeilingType" substitutionGroup="_StructuralComponent"/>
<!-- ================================================================================ -->
  <xs:complexType name="CeilingType">
    <xs:annotation>
      <xs:documentation>Comment describing CeilingType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="Structure" type="StructureType" substitutionGroup="_StructuralComponent"/>
<!-- ================================================================================ -->
  <xs:complexType name="StructureType">
    <xs:annotation>
      <xs:documentation>Comment describing StructureType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="Door" type="DoorType" substitutionGroup="_StructuralComponent"/>
<!-- ================================================================================ -->
  <xs:complexType name="DoorType">
    <xs:annotation>
      <xs:documentation>Comment describing DoorType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="Window" type="WindowType" substitutionGroup="_StructuralComponent"/>
<!-- ================================================================================ -->
  <xs:complexType name="WindowType">
    <xs:annotation>
      <xs:documentation>Comment describing WindowType</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractStructuralComponentType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="Unit" type="UnitType" substitutionGroup="_BuildingPart"/>
<!-- ================================================================================ -->
  <xs:complexType name="UnitType">
    <xs:annotation>
      <xs:documentation>Comment describing UnitType</xs:documentation>
```

```xml
		</xs:annotation>
		<xs:complexContent>
			<xs:extension base="AbstractBuildingPartType">
				<xs:attribute name="unitNo" type="xs:string" use="optional"/>
				<xs:attribute name="storeyNo" type="xs:nonNegativeInteger" use="optional"/>
				<xs:attribute name="landUse" type="landUseType" use="optional"/>
			</xs:extension>
		</xs:complexContent>
	</xs:complexType>
<!-- =========================================================================== -->
	<xs:element name="CarPark" type="CarParkType" substitutionGroup="_BuildingPart"/>
<!-- =========================================================================== -->
	<xs:complexType name="CarParkType">
		<xs:annotation>
			<xs:documentation>Comment describing CarParkType</xs:documentation>
		</xs:annotation>
		<xs:complexContent>
			<xs:extension base="AbstractBuildingPartType">
				<xs:attribute name="carparkNo" type="xs:string" use="optional"/>
			</xs:extension>
		</xs:complexContent>
	</xs:complexType>
<!-- =========================================================================== -->
	<xs:element name="ServiceRoom" type="ServiceRoomType" substitutionGroup="_BuildingPart"/>
<!-- =========================================================================== -->
	<xs:complexType name="ServiceRoomType">
		<xs:annotation>
			<xs:documentation>Comment describing ServiceRoomType</xs:documentation>
		</xs:annotation>
		<xs:complexContent>
			<xs:extension base="AbstractBuildingPartType"/>
		</xs:complexContent>
	</xs:complexType>
<!-- =========================================================================== -->
	<xs:element name="StorageRoom" type="StorageRoomType" substitutionGroup="_BuildingPart"/>
<!-- =========================================================================== -->
	<xs:complexType name="StorageRoomType">
		<xs:annotation>
			<xs:documentation>Comment describing StorageRoomType</xs:documentation>
		</xs:annotation>
		<xs:complexContent>
			<xs:extension base="AbstractBuildingPartType"/>
		</xs:complexContent>
	</xs:complexType>
<!-- =========================================================================== -->
	<xs:element name="Pathway" type="PathwayType" substitutionGroup="_BuildingPart"/>
<!-- =========================================================================== -->
	<xs:complexType name="PathwayType">
		<xs:annotation>
			<xs:documentation>Comment describing PathwayType</xs:documentation>
		</xs:annotation>
		<xs:complexContent>
			<xs:extension base="AbstractBuildingPartType"/>
		</xs:complexContent>
	</xs:complexType>
<!-- =========================================================================== -->
	<xs:element name="Balcony" type="BalconyType" substitutionGroup="_BuildingPart"/>
<!-- =========================================================================== -->
	<xs:complexType name="BalconyType">
		<xs:annotation>
			<xs:documentation>Comment describing BalconyType</xs:documentation>
		</xs:annotation>
		<xs:complexContent>
			<xs:extension base="AbstractBuildingPartType">
				<xs:attribute name="unitNo" type="xs:string" use="optional"/>
			</xs:extension>
		</xs:complexContent>
	</xs:complexType>
<!-- =========================================================================== -->
	<xs:element name="Roof" type="RoofType" substitutionGroup="_BuildingPart"/>
<!-- =========================================================================== -->
	<xs:complexType name="RoofType">
```

```xml
            <xs:annotation>
                <xs:documentation>Comment describing RoofType</xs:documentation>
            </xs:annotation>
            <xs:complexContent>
                <xs:extension base="AbstractBuildingPartType"/>
            </xs:complexContent>
        </xs:complexType>
    <!-- ================================================================================= -->
        <xs:element name="BuildingPart" type="BuildingPartType" substitutionGroup="_BuildingPart"/>
    <!-- ================================================================================= -->
        <xs:complexType name="BuildingPartType">
            <xs:annotation>
                <xs:documentation>Comment describing BuildingPartType</xs:documentation>
            </xs:annotation>
            <xs:complexContent>
                <xs:extension base="AbstractBuildingPartType"/>
            </xs:complexContent>
        </xs:complexType>
    <!-- ================================================================================= -->
        <xs:complexType name="addressType">
            <xs:sequence>
                <xs:element name="Address" type="addreType"/>
            </xs:sequence>
        </xs:complexType>
    <!-- ================================================================================= -->
        <xs:complexType name="addreType">
            <xs:annotation>
                <xs:documentation>Type describing the address element.</xs:documentation>
            </xs:annotation>
            <xs:sequence>
                <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
            </xs:sequence>
            <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
            <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
            <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
            <xs:attribute name="streetName" type="xs:string" use="optional"/>
            <xs:attribute name="streetType" type="xs:string" use="optional"/>
            <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
            <xs:attribute name="Suburb" type="xs:string" use="optional"/>
            <xs:attribute name="city" type="xs:string" use="optional"/>
            <xs:attribute name="state" type="xs:string" use="optional"/>
            <xs:attribute name="postCode" type="xs:string" use="optional"/>
            <xs:attribute name="country" type="xs:string" use="optional"/>
            <xs:attribute name="desc" type="xs:string" use="optional"/>
        </xs:complexType>
    <!-- ================================================================================= -->
        <xs:complexType name="geocodedAddressType">
            <xs:sequence>
                <xs:element name="AddressPoint" type="addressPointType"/>
            </xs:sequence>
        </xs:complexType>
    <!-- ================================================================================= -->
        <xs:complexType name="addressPointType">
            <xs:annotation>
                <xs:documentation>Type describing the geocoded address element.</xs:documentation>
            </xs:annotation>
            <xs:sequence>
                <xs:element name="referencePoint" type="gml:PointPropertyType"/>
            </xs:sequence>
            <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
        </xs:complexType>
    <!-- ================================================================================= -->
    <!-- ================================================================================= -->
        <xs:simpleType name="landUseType">
            <xs:restriction base="xs:string">
                <xs:enumeration value="residential"/>
                <xs:enumeration value="industry"/>
                <xs:enumeration value="mixedUse"/>
                <xs:enumeration value="mining"/>
                <xs:enumeration value="agriculture"/>
                <xs:enumeration value="road"/>
                <xs:enumeration value="sea"/>
```

```
        </xs:restriction>
    </xs:simpleType>
<!-- ================================================================================ -->
</xs:schema>
```

D.7 XML Schema for 3DCDM Land Model

```xml
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/land/1.0"
   xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
   xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/land/1.0"
   elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
    All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University of
    Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- ================================================================================ -->
  <xs:element name="Land" type="landType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="landType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of land.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
        </xs:sequence>
        <xs:attribute name="landUse" type="xs:string" use="optional"/>
        <xs:attribute name="area" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="addressType">
    <xs:sequence>
      <xs:element name="Address" type="addreType"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="addreType">
    <xs:annotation>
      <xs:documentation>Type describing the address element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
    <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
    <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
    <xs:attribute name="streetName" type="xs:string" use="optional"/>
    <xs:attribute name="streetType" type="xs:string" use="optional"/>
    <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
    <xs:attribute name="Suburb" type="xs:string" use="optional"/>
    <xs:attribute name="city" type="xs:string" use="optional"/>
    <xs:attribute name="state" type="xs:string" use="optional"/>
    <xs:attribute name="postCode" type="xs:string" use="optional"/>
    <xs:attribute name="country" type="xs:string" use="optional"/>
```

```
        <xs:attribute name="desc" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="geocodedAddressType">
        <xs:sequence>
            <xs:element name="AddressPoint" type="addressPointType"/>
        </xs:sequence>
    </xs:complexType>
<!-- =================================================================================== -->
    <xs:complexType name="addressPointType">
        <xs:annotation>
            <xs:documentation>Type describing the geocoded address element.</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="referencePoint" type="gml:PointPropertyType"/>
        </xs:sequence>
        <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
    </xs:complexType>
<!-- =================================================================================== -->
</xs:schema>
```

D.8 XML Schema for 3DCDM Tunnel Model

```
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/tunnel/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/tunnel/1.0"
   elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
    All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University of
    Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- =========================================================================== -->
  <xs:element name="Tunnel" type="TunnelType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- =========================================================================== -->
  <xs:complexType name="TunnelType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of tunnels.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation>  </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="terrainIntersection" type="gml:MultiCurvePropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="consistsOfStructuralComponent" type="StructuralComponentPropertyType" minOccurs="0"
          maxOccurs="unbounded"/>
          <xs:element name="consistsOfSpace" type="SpacePropertyType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="usage" type="xs:string" use="optional"/>
        <xs:attribute name="constructionYear" type="xs:gYear" use="optional"/>
        <xs:attribute name="heightBelowGround" type="xs:double" use="optional"/>
        <xs:attribute name="length" type="xs:double" use="optional"/>
        <xs:attribute name="width" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:complexType name="SpacePropertyType">
    <xs:sequence minOccurs="0">
      <xs:element ref="Space"/>
    </xs:sequence>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:element name="Space" type="SpaceType"/>
<!-- =========================================================================== -->
  <xs:complexType name="SpaceType">
    <xs:annotation>
      <xs:documentation>Type describing the space element of the tunnel.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
```

```
            </xs:sequence>
            <xs:attribute name="area" type="xs:double" use="optional"/>
            <xs:attribute name="volume" type="xs:double" use="optional"/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>
<!-- ========================================================================================= -->
   <xs:complexType name="StructuralComponentPropertyType">
      <xs:sequence minOccurs="0">
         <xs:element ref="_StructuralComponent"/>
      </xs:sequence>
   </xs:complexType>
<!-- ========================================================================================= -->
   <xs:element name="_StructuralComponent" type="AbstractStructuralComponentType" abstract="true"
   substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ========================================================================================= -->
   <xs:complexType name="AbstractStructuralComponentType" abstract="true">
      <xs:annotation>
         <xs:documentation>Type describing the structural componenet of the tunnel.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
         <xs:extension base="root:AbstractPhysicalPropertyObjectType">
            <xs:sequence>
               <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
               <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
               maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute name="width" type="xs:double" use="optional"/>
            <xs:attribute name="length" type="xs:double" use="optional"/>
            <xs:attribute name="area" type="xs:double" use="optional"/>
            <xs:attribute name="volume" type="xs:double" use="optional"/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>
<!-- ========================================================================================= -->
   <xs:element name="Wall" type="WallType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================================= -->
   <xs:complexType name="WallType">
      <xs:annotation>
         <xs:documentation>Type describing the wall element of the tunnel..</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
         <xs:extension base="AbstractStructuralComponentType"/>
      </xs:complexContent>
   </xs:complexType>
<!-- ========================================================================================= -->
   <xs:element name="Floor" type="FloorType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================================= -->
   <xs:complexType name="FloorType">
      <xs:annotation>
         <xs:documentation>Type describing the floor element of the tunnel.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
         <xs:extension base="AbstractStructuralComponentType"/>
      </xs:complexContent>
   </xs:complexType>
<!-- ========================================================================================= -->
   <xs:element name="Ceiling" type="CeilingType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================================= -->
   <xs:complexType name="CeilingType">
      <xs:annotation>
         <xs:documentation>Type describing the ceiling element of the tunnel.</xs:documentation>
      </xs:annotation>
      <xs:complexContent>
         <xs:extension base="AbstractStructuralComponentType"/>
      </xs:complexContent>
   </xs:complexType>
<!-- ========================================================================================= -->
   <xs:element name="Structure" type="StructureType" substitutionGroup="_StructuralComponent"/>
<!-- ========================================================================================= -->
   <xs:complexType name="StructureType">
      <xs:annotation>
```

```xml
            <xs:documentation>Type describing the any elements of the tunnel.</xs:documentation>
        </xs:annotation>
        <xs:complexContent>
            <xs:extension base="AbstractStructuralComponentType"/>
        </xs:complexContent>
    </xs:complexType>
<!-- ====================================================================== -->
    <xs:complexType name="addressType">
        <xs:sequence>
            <xs:element name="Address" type="addreType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ====================================================================== -->
    <xs:complexType name="addreType">
        <xs:annotation>
            <xs:documentation>Type describing the address element.</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
        <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
        <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
        <xs:attribute name="streetName" type="xs:string" use="optional"/>
        <xs:attribute name="streetType" type="xs:string" use="optional"/>
        <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
        <xs:attribute name="Suburb" type="xs:string" use="optional"/>
        <xs:attribute name="city" type="xs:string" use="optional"/>
        <xs:attribute name="state" type="xs:string" use="optional"/>
        <xs:attribute name="postCode" type="xs:string" use="optional"/>
        <xs:attribute name="country" type="xs:string" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- ====================================================================== -->
    <xs:complexType name="geocodedAddressType">
        <xs:sequence>
            <xs:element name="AddressPoint" type="addressPointType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ====================================================================== -->
    <xs:complexType name="addressPointType">
        <xs:annotation>
            <xs:documentation>Type describing the geocoded address element.</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="referencePoint" type="gml:PointPropertyType"/>
        </xs:sequence>
        <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
    </xs:complexType>
<!-- ====================================================================== -->
</xs:schema>
```

D.9 XML Schema for 3DCDM UtilityNetwork Model

```
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/utility/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/utility/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
    All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University of
    Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- ================================================================================ -->
  <xs:element name="_UtilityNetwork" type="AbstractUtilityNetworkType" abstract="true"
  substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="AbstractUtilityNetworkType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of any utility networks.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:MultiSolidPropertyType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="consistsOfNetworkComponent" type="NetworkComponentPropertyType" minOccurs="0"
          maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="networkLength" type="xs:double" use="optional"/>
        <xs:attribute name="constructionYear" type="xs:gYear" use="optional"/>
        <xs:attribute name="networkHeightBelowGround" type="xs:double" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="NetworkComponentPropertyType">
    <xs:sequence minOccurs="0">
      <xs:element ref="NetworkComponent"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="NetworkComponent" type="NetworkComponentType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="NetworkComponentType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of network
      componenets.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
          maxOccurs="1"/>
```

```
                <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
                maxOccurs="1"/>
                <xs:element name="representedBySolid" type="gml:SolidPropertyType" minOccurs="0" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute name="material" type="xs:string" use="optional"/>
            <xs:attribute name="width" type="xs:double" use="optional"/>
            <xs:attribute name="length" type="xs:double" use="optional"/>
            <xs:attribute name="area" type="xs:double" use="optional"/>
            <xs:attribute name="volume" type="xs:double" use="optional"/>
        </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:element name="WaterNetwork" type="WaterNetworkType" substitutionGroup="_UtilityNetwork"/>
<!-- =========================================================================== -->
  <xs:complexType name="WaterNetworkType">
    <xs:annotation>
      <xs:documentation>Type describing the water network element.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractUtilityNetworkType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:element name="TelecommunicationNetwork" type="TelecommunicationNetworkType"
  substitutionGroup="_UtilityNetwork"/>
<!-- =========================================================================== -->
  <xs:complexType name="TelecommunicationNetworkType">
    <xs:annotation>
      <xs:documentation>Type describing the telecommunication network element.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractUtilityNetworkType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:element name="WasteNetwork" type="WasteNetworkType" substitutionGroup="_UtilityNetwork"/>
<!-- =========================================================================== -->
  <xs:complexType name="WasteNetworkType">
    <xs:annotation>
      <xs:documentation>Type describing the waste network element.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractUtilityNetworkType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:element name="ElectricityNetwork" type="ElectricityNetworkType" substitutionGroup="_UtilityNetwork"/>
<!-- =========================================================================== -->
  <xs:complexType name="ElectricityNetworkType">
    <xs:annotation>
      <xs:documentation>Type describing the electricity network element.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractUtilityNetworkType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:complexType name="addressType">
    <xs:sequence>
      <xs:element name="Address" type="addreType"/>
    </xs:sequence>
  </xs:complexType>
<!-- =========================================================================== -->
  <xs:complexType name="addreType">
    <xs:annotation>
      <xs:documentation>Type describing the address element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
```

```
        <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
        <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
        <xs:attribute name="streetName" type="xs:string" use="optional"/>
        <xs:attribute name="streetType" type="xs:string" use="optional"/>
        <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
        <xs:attribute name="Suburb" type="xs:string" use="optional"/>
        <xs:attribute name="city" type="xs:string" use="optional"/>
        <xs:attribute name="state" type="xs:string" use="optional"/>
        <xs:attribute name="postCode" type="xs:string" use="optional"/>
        <xs:attribute name="country" type="xs:string" use="optional"/>
        <xs:attribute name="desc" type="xs:string" use="optional"/>
    </xs:complexType>
<!-- ====================================================================== -->
    <xs:complexType name="geocodedAddressType">
        <xs:sequence>
            <xs:element name="AddressPoint" type="addressPointType"/>
        </xs:sequence>
    </xs:complexType>
<!-- ====================================================================== -->
    <xs:complexType name="addressPointType">
        <xs:annotation>
            <xs:documentation>Type describing the geocoded address element.</xs:documentation>
        </xs:annotation>
        <xs:sequence>
            <xs:element name="referencePoint" type="gml:PointPropertyType"/>
        </xs:sequence>
        <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
    </xs:complexType>
<!-- ====================================================================== -->
</xs:schema>
```

D.10 XML Schema for 3DCDM PhysicalPropertyObject Model

```
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/ppo/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/ppo/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
```

```
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- ============================================================================== -->
  <xs:element name="PhysicalPropertyObject" type="PPOType" substitutionGroup="root:_PhysicalPropertyObject"/>
<!-- ============================================================================== -->
  <xs:complexType name="PPOType">
    <xs:annotation>
      <xs:documentation>Type describing the elements, attributes, and associations of any physical property
      objects.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractPhysicalPropertyObjectType">
        <xs:sequence>
          <xs:annotation>
            <xs:documentation> </xs:documentation>
          </xs:annotation>
          <xs:element name="address" type="addressType" minOccurs="0" maxOccurs="1"/>
          <xs:element name="representedByMultiPoint" type="gml:MultiPointPropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiCurve" type="gml:MultiCurvePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedByMultiSurface" type="gml:MultiSurfacePropertyType" minOccurs="0"
          maxOccurs="1"/>
          <xs:element name="representedBySolid" type="gml:MultiSolidPropertyType" minOccurs="0" maxOccurs="1"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ============================================================================== -->
  <xs:complexType name="addressType">
    <xs:sequence>
      <xs:element name="Address" type="addreType"/>
    </xs:sequence>
  </xs:complexType>
<!-- ============================================================================== -->
  <xs:complexType name="addreType">
    <xs:annotation>
      <xs:documentation>Type describing the address element.</xs:documentation>
    </xs:annotation>
    <xs:sequence>
      <xs:element name="geocodedAddress" type="geocodedAddressType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="flatNumber" type="xs:string" use="optional"/>
    <xs:attribute name="levelNumber" type="xs:string" use="optional"/>
    <xs:attribute name="propertyNumber" type="xs:string" use="optional"/>
    <xs:attribute name="streetName" type="xs:string" use="optional"/>
    <xs:attribute name="streetType" type="xs:string" use="optional"/>
    <xs:attribute name="streetSuffix" type="xs:string" use="optional"/>
    <xs:attribute name="Suburb" type="xs:string" use="optional"/>
    <xs:attribute name="city" type="xs:string" use="optional"/>
    <xs:attribute name="state" type="xs:string" use="optional"/>
```

```xml
      <xs:attribute name="postCode" type="xs:string" use="optional"/>
      <xs:attribute name="country" type="xs:string" use="optional"/>
      <xs:attribute name="desc" type="xs:string" use="optional"/>
   </xs:complexType>
<!-- ================================================================================= -->
   <xs:complexType name="geocodedAddressType">
      <xs:sequence>
         <xs:element name="AddressPoint" type="addressPointType"/>
      </xs:sequence>
   </xs:complexType>
<!-- ================================================================================= -->
   <xs:complexType name="addressPointType">
      <xs:annotation>
         <xs:documentation>Type describing the geocoded address element.</xs:documentation>
      </xs:annotation>
      <xs:sequence>
         <xs:element name="referencePoint" type="gml:PointPropertyType"/>
      </xs:sequence>
      <xs:attribute name="pntRef" type="xs:IDREF" use="required"/>
   </xs:complexType>
<!-- ================================================================================= -->
</xs:schema>
```

D.11 XML Schema for 3DCDM Terrain Model

```xml
<!-- 3DCDM Version No. 1.0, December 2012, Building Module -->
<!-- 3DCDM - application schema for 3D Cadastres -->
<!-- edited with XMLSpy v2012 rel. 2 (http://www.altova.com) by Ali Aien (Centre for SDIs and Land Administration) -->
<!-- Date Posted: 12/12/2012 -->
<!-- For further information see: http://www.csdila.unimelb.edu.au/people/ali-aien.html -->
<xs:schema
  xmlns="http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0"
  xmlns:root="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  targetNamespace="http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0"
  elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.0">
  <xs:annotation>
    <xs:documentation>
    All rights belong to the Centre for SDIs and Land Administration, Department of Infrastructure Engineering, The University of
    Melbourne. To obtain additional right of use, visit http://www.csdila.unimelb.edu.au/
    </xs:documentation>
  </xs:annotation>
  <xs:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <xs:import namespace="http://www.csdila.unimelb.edu.au/3DCDM/1.0"
  schemaLocation="http://www.csdila.unimelb.edu.au/3DCDM/schema/3DCDMBase.xsd"/>
<!-- ================================================================================ -->
  <xs:element name="Terrain" type="terrainType" substitutionGroup="root:_UrbanObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="terrainType">
    <xs:annotation>
      <xs:documentation>Type describing the terrain element of the model.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractUrbanObjectType">
        <xs:sequence>
          <xs:element name="terrainSource" type="terrainSourceType" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="_TerrainSource" type="AbstractTerrainSourceType" abstract="true"
  substitutionGroup="root:_UrbanObject"/>
<!-- ================================================================================ -->
  <xs:complexType name="AbstractTerrainSourceType">
    <xs:annotation>
      <xs:documentation>Type describing the abstract superclass of terrain sorces. </xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="root:AbstractUrbanObjectType"/>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="terrainSourceType">
    <xs:annotation>
      <xs:documentation>Comment describing terrainSourceType </xs:documentation>
    </xs:annotation>
    <xs:sequence minOccurs="0">
      <xs:element ref="_TerrainSource"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="TIN" type="tinType" substitutionGroup="_TerrainSource"/>
<!-- ================================================================================ -->
  <xs:complexType name="tinType">
    <xs:annotation>
      <xs:documentation>Type describing the TIN element of the model.</xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractTerrainSourceType">
        <xs:sequence>
          <xs:element name="tinSource" type="tinSourceType"/>
        </xs:sequence>
      </xs:extension>
```

```
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:complexType name="tinSourceType">
    <xs:sequence minOccurs="0">
      <xs:element ref="gml:TriangulatedSurface"/>
    </xs:sequence>
  </xs:complexType>
<!-- ================================================================================ -->
  <xs:element name="DEM" type="demType" substitutionGroup="_TerrainSource"/>
<!-- ================================================================================ -->
  <xs:complexType name="demType">
    <xs:annotation>
      <xs:documentation>Type describing the DEM element of the model. </xs:documentation>
    </xs:annotation>
    <xs:complexContent>
      <xs:extension base="AbstractTerrainSourceType">
        <xs:sequence>
          <xs:element name="demSource" type="gml:MultiPointPropertyType"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
<!-- ================================================================================ -->
</xs:schema>
```

Appendix E- EXAMPLE OF A 3DCDM DATASET

APPENDIX E: EXAMPLE OF A 3DCDM DATASET

E.1 XML Schema of 3DCDM Root Model

```xml
<!-- ==================================== Root Element ================================== -->
<?xml version="1.0" encoding="utf-8"?>
<UrabnCadastralModel
  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:lpo="http://www.csdila.unimelb.edu.au/3DCDM/lpo/1.0"
  xmlns:bild="http://www.csdila.unimelb.edu.au/3DCDM/building/1.0"
  xmlns:ownr="http://www.csdila.unimelb.edu.au/3DCDM/owner/1.0"
  xmlns:ppo="http://www.csdila.unimelb.edu.au/3DCDM/ppo/1.0"
  xmlns:land="http://www.csdila.unimelb.edu.au/3DCDM/land/1.0"
  xmlns:trn="http://www.csdila.unimelb.edu.au/3DCDM/terrain/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:unwk="http://www.csdila.unimelb.edu.au/3DCDM/utility/1.0"
  xmlns:tunl="http://www.csdila.unimelb.edu.au/3DCDM/tunnel/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/ppo/1.0
  http://www.csdila.unimelb.edu.au/3DCDM/schema/PhysicalPropertyObject.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/land/1.0 http://www.csdila.unimelb.edu.au/3DCDM/schema/Land.xsd
  http://www.csdila.unimelb.edu.au/3DCDM/utility/1.0 http://www.csdila.unimelb.edu.au/3DCDM/schema/UtilityNetwork.xsd
  http://www.csdila.unimelb.edu.au/3DCDM/tunnel/1.0 http://www.csdila.unimelb.edu.au/3DCDM/schema/Tunnel.xsd
  http://www.csdila.unimelb.edu.au/3DCDM/terrain/1.0 http://www.csdila.unimelb.edu.au/3DCDM/schema/Terrain.xsd ">
<!-- ==================================== Metadata ========================================== -->
  <gml:name>EXAMPLE OF A 3DCDM DATASET- CHAPTER 8</gml:name>
  <gml:boundedBy>
    <gml:Envelope srsDimension="3" srsName="urn:ogc:def:crs,crs:EPSG::25832,crs:EPSG::5783">
      <gml:lowerCorner>990 990 0</gml:lowerCorner>
      <gml:upperCorner>1042 1018 10</gml:upperCorner>
    </gml:Envelope>
  </gml:boundedBy>
  <metricUnit>
    <MetricUnit directionUnit="decimal dd.mm.ss" angularUnit="decimal dd.mm.ss" temperatureUnit="celsius"
    volumeUnit="cubicMeter" linearUnit="meter" areaUnit="squareMeter" pressureUnit="milliBars"/>
  </metricUnit>
  <!-- ======================================= 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>
```

```xml
                        </gml:LinearRing>
                    </gml:exterior>
                  </gml:Triangle>
                </gml:trianglePatches>
              </gml:TriangulatedSurface>
            </trn:tinSource>
          </trn:TIN>
        </trn:terrainSource>
      </trn:Terrain>
    </physicalObjectMember>
  </UrbanModel>
</physicalModel>
<!-- ================================== Physical Model  =======================================-->
<physicalModel>
  <UrbanModel>
    <physicalObjectMember>
      <bild:Building gml:id="DCDM_Building_Unit1" landUse="residential" constructionYear="1994" buildingHeight="6"
      noOfStoreysAboveGround="2" noOfStoreysBelowGround="0">
        <!-- ============================== 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  ============================-->
            <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  =================================-->
            <!-- ====================== Floor-Unit1  ====================================-->
            <bild:consistsOfStructuralComponent>
              <bild:Floor gml:id="DCDM_Floor_Unit_1">
                <bild:representedByMultiSurface>
                  <gml:MultiSurface gml:id="DCDM_Floor_Unit-1">
                    <gml:surfaceMember>
                      <gml:CompositeSurface gml:id="DCDM_Floor-Unit-1">
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_UNIT_1_Floor_Interior">
                            <gml:name>UNIT_1_Floor_Interior</gml:name>
                            <gml:exterior>
                              <gml:LinearRing>
                                <gml:posList>1000.630 1000.000 0.100 1024.70 1000.000 0.100 1024.70 1005.030
                                0.100 1000.655 1005.030 0.100  1000.630 1000.000 0.100
                                </gml:posList>
                              </gml:LinearRing>
                            </gml:exterior>
                          </gml:Polygon>
                        </gml:surfaceMember>
                        <gml:surfaceMember>
```

```
            <gml:Polygon gml:id="GML_UNIT_1_Floor_Exterior">
              <gml:name>UNIT_1_Floor_Exterior</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1000.630 1000.000 0 1024.70 1000.000 0 1024.70 1005.030 0 1000.655
                  1005.030 0 1000.630 1000.000 0
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_South">
              <gml:name>UNIT_1_Floor_Side_South</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1000.630 1000.000 0.000 1024.700 1000.000 0.000 1024.700 1000.000
                  0.100 1000.630 1000.00 0.100 1000.630 1000.000 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_North">
              <gml:name>UNIT_1_Floor_Side_North</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1000.655 1005.030 0.000 1024.700 1005.030 0.000 1024.700 1005.030
                  0.100 1000.655 1005.030 0.100  1000.655 1005.030 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_Right">
              <gml:name>UNIT_1_Floor_Side_Right</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1024.700 1000.000 0.000 1024.700 1005.030 0.000 1024.700 1005.030
                  0.100 1024.700 1000.000 0.100  1024.700 1000.000 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_UNIT_1_Floor_Side_Left">
              <gml:name>UNIT_1_Floor_Side_Left</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1000.630 1000.000 0.000 1000.655 1005.030 0.000 1000.655 1005.030
                  0.100 1000.630 1000.000 0.100  1000.630 1000.000 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
        </gml:CompositeSurface>
      </gml:surfaceMember>
    </gml:MultiSurface>
  </bild:representedByMultiSurface>
</bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ============================ Wall-South-Unit1 ==========================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_South_Unit_1">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_South_Unit-1">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_South-Unit-1">
```

```
&lt;gml:surfaceMember&gt;
  &lt;gml:Polygon gml:id="GML_UNIT_1_Wall_South_Interior"&gt;
    &lt;gml:name&gt;UNIT_1_Wall_South_Interior&lt;/gml:name&gt;
    &lt;gml:exterior&gt;
      &lt;gml:LinearRing&gt;
        &lt;gml:posList&gt;1024.70 1000.20 0.100 1024.70 1000.20 3.00 1020.640 1000.20 3.00
        1020.640 1000.20 6.00 1000.00 1000.20 6.00 1000.00 1000.20 3.00 1000.630 1000.20
        3.00 1000.630 1000.20 0.10 1024.70 1000.20 0.100
        &lt;/gml:posList&gt;
      &lt;/gml:LinearRing&gt;
    &lt;/gml:exterior&gt;
  &lt;/gml:Polygon&gt;
&lt;/gml:surfaceMember&gt;
&lt;gml:surfaceMember&gt;
  &lt;gml:Polygon gml:id="GML_UNIT_1_Wall_South_Exterior"&gt;
    &lt;gml:name&gt;UNIT_1_Floor_South_Exterior&lt;/gml:name&gt;
    &lt;gml:exterior&gt;
      &lt;gml:LinearRing&gt;
        &lt;gml:posList&gt;1024.70 1000.00 0.100 1024.70 1000.00 3.00 1020.640 1000.00 3.00
        1020.640 1000.00 6.00 1000.00 1000.00 6.00 1000.00 1000.00 3.00 1000.630
        1000.000 3.00 1000.630 1000.000 0.10 1024.70 1000.00 0.100
        &lt;/gml:posList&gt;
      &lt;/gml:LinearRing&gt;
    &lt;/gml:exterior&gt;
  &lt;/gml:Polygon&gt;
&lt;/gml:surfaceMember&gt;
&lt;gml:surfaceMember&gt;
  &lt;gml:Polygon gml:id="GML_UNIT_1_Wall_South_Upper_1"&gt;
    &lt;gml:name&gt;UNIT_1_Wall_South_Upper&lt;/gml:name&gt;
    &lt;gml:exterior&gt;
      &lt;gml:LinearRing&gt;
        &lt;gml:posList&gt;1024.70 1000.00 3.00 1024.70 1000.20 3.00 1020.640 1000.20 3.00
        1020.640 1000.000 3.00 1024.70 1000.00 3.00
        &lt;/gml:posList&gt;
      &lt;/gml:LinearRing&gt;
    &lt;/gml:exterior&gt;
  &lt;/gml:Polygon&gt;
&lt;/gml:surfaceMember&gt;
&lt;gml:surfaceMember&gt;
  &lt;gml:Polygon gml:id="GML_UNIT_1_Wall_South_Upper_2"&gt;
    &lt;gml:name&gt;UNIT_1_Wall_South_Upper&lt;/gml:name&gt;
    &lt;gml:exterior&gt;
      &lt;gml:LinearRing&gt;
        &lt;gml:posList&gt;1020.640 1000.20 3.00 1020.640 1000.20 6.00 1020.640 1000.000 6.00
        1020.640 1000.000 3.00 1020.640 1000.20 3.00
        &lt;/gml:posList&gt;
      &lt;/gml:LinearRing&gt;
    &lt;/gml:exterior&gt;
  &lt;/gml:Polygon&gt;
&lt;/gml:surfaceMember&gt;
&lt;gml:surfaceMember&gt;
  &lt;gml:Polygon gml:id="GML_UNIT_1_Wall_South_Upper_3"&gt;
    &lt;gml:name&gt;UNIT_1_Wall_South_Upper&lt;/gml:name&gt;
    &lt;gml:exterior&gt;
      &lt;gml:LinearRing&gt;
        &lt;gml:posList&gt;1020.640 1000.20 6.00 1000.00 1000.20 6.00 1000.00 1000.000 6.00
        1020.640 1000.000 6.00 1020.640 1000.20 6.00
        &lt;/gml:posList&gt;
      &lt;/gml:LinearRing&gt;
    &lt;/gml:exterior&gt;
  &lt;/gml:Polygon&gt;
&lt;/gml:surfaceMember&gt;
&lt;gml:surfaceMember&gt;
  &lt;gml:Polygon gml:id="GML_UNIT_1_Wall_South_Lower"&gt;
    &lt;gml:name&gt;UNIT_1_Wall_South_Lower&lt;/gml:name&gt;
    &lt;gml:exterior&gt;
      &lt;gml:LinearRing&gt;
        &lt;gml:posList&gt;1000.630 1000.00 0.10 1024.70 1000.00 0.10 1024.70 1000.200 0.10
        1000.630 1000.200 0.10 1000.630 1000.00 0.10
        &lt;/gml:posList&gt;
      &lt;/gml:LinearRing&gt;
    &lt;/gml:exterior&gt;
```

```xml
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Wall_South_Side_Right">
                <gml:name>UNIT_1_Wall_South_Side_Right</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1000.00 0.10 1024.70 1000.20 0.10 1024.70 1000.200 3.0
                    1024.70 1000.00 3.0 1024.70 1000.00 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Wall_South_Side_Left_1">
                <gml:name>UNIT_1_Wall_South_Side_Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.630 1000.00 0.10 1000.630 1000.20 0.10 1000.630 1000.20 3.0
                    1000.630 1000.00 3.0 1000.630 1000.00 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Wall_South_Side_Left_2">
                <gml:name>UNIT_1_Wall_South_Side_Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.00 1000.00 3 1000.630 1000.00 3.0 1000.630 1000.20 3.0 1000.00
                    1000.20 3.0 1000.00 1000.00 3
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Wall_South_Side_Left_3">
                <gml:name>UNIT_1_Wall_South_Side_Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.00 1000.00 3 1000.00 1000.20 3.0 1000.00 1000.20 6.0 1000.00
                    1000.00 6.0 1000.00 1000.00 3
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ============================ Wall-North-Unit1 ==============================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_North_Unit_1">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_North_Unit-1">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_North-Unit-1">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Interior">
                <gml:name>UNIT_1_Wall_North_Interior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1024.70 1004.930 0.100 1024.70 1004.930 3.00 1020.640 1004.930
                    3.00 1020.640 1004.930 6.00 1000.00 1004.930 6.00 1000.00 1004.930 3.00 1000.655
                    1004.930 3.00 1000.655 1004.930 0.10 1024.70 1004.930 0.100
```

```xml
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Exterior">
    <gml:name>UNIT_1_Floor_North_Exterior</gml:name>
    <gml:exterior>
      <!-- -->
      <gml:LinearRing>
        <gml:posList>1024.70 1005.030 0.100 1024.70 1005.030 3.00 1020.640 1005.030
        3.00 1020.640 1005.030 6.00 1000.00 1005.030 6.00 1000.00 1005.030 3.00 1000.655
        1005.030 3.00 1000.655 1005.030 0.10 1024.70 1005.030 0.100
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Upper_1">
    <gml:name>UNIT_1_Wall_North_Upper</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1024.70 1004.930 3.00 1024.70 1005.030 3.00 1020.640 1005.030 3.00
        1020.640 1004.930 3.00 1024.70 1004.930 3.00
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Upper_2">
    <gml:name>UNIT_1_Wall_North_Upper</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1020.640 1004.930 3.00 1020.640 1004.930 6.00 1020.640 1005.030
        6.00 1020.640 1005.030 3.00 1020.640 1004.930 3.00
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Upper_3">
    <gml:name>UNIT_1_Wall_North_Upper</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1020.640 1004.930 6.00 1020.640 1005.030 6.00 1000.00 1005.030
        6.00 1000.00 1004.930 6.00 1020.640 1004.930 6.00
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Lower">
    <gml:name>UNIT_1_Wall_North_Lower</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1000.655 1004.930 0.10 1024.70 1004.930 0.10 1024.70 1005.030 0.10
        1000.655 1005.030 0.10 1000.655 1004.930 0.10
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Side_Right">
    <gml:name>UNIT_1_Wall_North_Side_Right</gml:name>
    <gml:exterior>
      <gml:LinearRing>
```

```xml
                <gml:posList>1024.70 1004.930 0.10 1024.70 1005.030 0.10 1024.70 1005.030 3.0
                1024.70 1004.930 3.0 1024.70 1004.930 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Side_Left_1">
            <gml:name>UNIT_1_Wall_North_Side_Left</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1000.655 1004.930 0.10 1000.655 1005.030 0.10 1000.655 1005.030
                3.0 1000.655 1004.930 3.0 1000.655 1004.930 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Side_Left_2">
            <gml:name>UNIT_1_Wall_North_Side_Left</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1000.00 1004.930 3 1000.655 1004.930 3.0 1000.655 1005.030 3.0
                1000.00 1005.030 3.0 1000.00 1004.930 3
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Side_Left_3">
            <gml:name>UNIT_1_Wall_North_Side_Left</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1000.00 1004.930 3.0 1000.00 1005.030 3.0 1000.00 1005.030 6.0
                1000.00 1004.930 6.0 1000.00 1004.930 3
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
      </gml:CompositeSurface>
    </gml:surfaceMember>
   </gml:MultiSurface>
  </bild:representedByMultiSurface>
 </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ====================== Floor-between-Unit1-Unit3 ==============================-->
<bild:consistsOfStructuralComponent>
 <bild:Floor gml:id="DCDM_Floor_between_Unit1_Unit3_Lower0.10">
  <bild:representedByMultiSurface>
   <gml:MultiSurface gml:id="DCDM_Floor_between_Unit1_Unit3-Lower0.10">
    <gml:surfaceMember>
      <gml:CompositeSurface gml:id="DCDM_Floor_between_Unit1-Unit3-Lower0.10">
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_between_Unit1_Unit3_Interior">
            <gml:name>Floor_between_Unit1_Unit3_Interior</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.70 1000.00 0.100 1024.90 1000.00 0.10 1024.90 1005.030 0.10
                1024.70 1005.030 0.10 1024.70 1000.00 0.100
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_between_Unit1_Unit3_Exterior">
            <gml:name>Floor_between_Unit1_Unit3_Exterior</gml:name>
            <gml:exterior>
```

```xml
                <gml:LinearRing>
                  <gml:posList>1024.70 1000.00 0 1024.90 1000.00 0 1024.90 1005.030 0 1024.70
                  1005.030 0 1024.70 1000.00 0
                </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_between_Unit1_Unit3_North">
              <gml:name>Floor_between_Unit1_Unit3_North</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1024.70 1005.030 0 1024.90 1005.030 0 1024.90 1005.030 0.10
                  1024.70 1005.030 0.10 1024.70 1005.030 0
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_between_Unit1_Unit3_South">
              <gml:name>Floor_between_Unit1_Unit3_South</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1024.70 1000.00 0.000 1024.900 1000.00 0.000 1024.900 1000.00
                  0.100 1024.70 1000.00 0.100  1024.70 1000.00 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_between_Unit1_Unit3_Side_Right">
              <gml:name>Floor_between_Unit1_Unit3_Side_Right</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1024.900 1000.000 0.000 1024.900 1005.030 0.000 1024.900 1005.030
                  0.100 1024.900 1000.000 0.100  1024.900 1000.000 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
          <gml:surfaceMember>
            <gml:Polygon gml:id="GML_between_Unit1_Unit3_Side_Left">
              <gml:name>Floor_between_Unit1_Unit3_Side_Left</gml:name>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>1024.700 1000.000 0.000 1024.700 1005.030 0.000 1024.700 1005.030
                  0.100 1024.700 1000.000 0.100  1024.700 1000.000 0.000
                  </gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
        </gml:CompositeSurface>
      </gml:surfaceMember>
    </gml:MultiSurface>
  </bild:representedByMultiSurface>
</bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ====================== Wall_between_Unit1_Unit3_1(lower)  ====================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_between_Unit1_Unit3_lower">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_between_Unit1_Unit3-lower">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_between_Unit1-Unit3-lower">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Interior_Unit1_lower">
                <gml:name>Wall_between_Unit1_Unit3_Interior_Unit1_lower</gml:name>
```

```
            <gml:exterior>
              <!-- -->
              <gml:LinearRing>
                <gml:posList>1024.700 1000.000 0.10 1024.700 1005.030 0.10 1024.700 1005.030
                3.0 1024.700 1000.000 3.0  1024.700 1000.000 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Interior_Unit3_lower">
            <gml:name>Wall_between_Unit1_Unit3_Interior_Unit3_lower</gml:name>
            <gml:exterior>
              <!-- -->
              <gml:LinearRing>
                <gml:posList>1024.900 1000.000 0.10 1024.900 1005.030 0.10 1024.900 1005.030
                3.0 1024.900 1000.000 3.0  1024.900 1000.000 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Floor_lower">
            <gml:name>Wall_between_Unit1_Unit3_Floor_lower</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.700 1000.000 0.10 1024.900 1000.00 0.10 1024.900 1005.030
                0.10 1024.700 1005.030 0.10  1024.700 1000.000 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Ceiling_lower">
            <gml:name>Wall_between_Unit1_Unit3_Ceiling_lower</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.700 1000.000 3.0 1024.900 1000.00 3.0 1024.900 1005.030 3.0
                1024.700 1005.030 3.0  1024.700 1000.000 3.0
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Side_North_lower">
            <gml:name>Wall_between_Unit1_Unit3_Side_North_lower</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.700 1005.030 0.10 1024.900 1005.030 0.10 1024.900 1005.030
                3.0 1024.700 1005.030 3.0  1024.700 1005.030 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Side_South_lower">
            <gml:name>Wall_between_Unit1_Unit3_Side_South_lower</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.700 1000.00 0.10 1024.900 1000.00 0.10 1024.900 1000.00 3.0
                1024.700 1000.00 3.0  1024.700 1000.00 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
      </gml:CompositeSurface>
```

```
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Wall>
    </bild:consistsOfStructuralComponent>
    <!-- ======================== Wall_between_Unit1_Unit3_1(upper)  =========================-->
    <bild:consistsOfStructuralComponent>
      <bild:Wall gml:id="DCDM_Wall_between_Unit1_Unit3_upper">
        <bild:representedByMultiSurface>
          <gml:MultiSurface gml:id="DCDM_Wall_between_Unit1_Unit3-upper">
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM_Wall_between_Unit1-Unit3-upper">
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Interior_Unit1_upper">
                    <gml:name>Wall_between_Unit1_Unit3_Interior_Unit1_upper</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1020.640 1000.000 3.0 1020.640 1005.030 3.0 1020.640 1005.030 6.0
                        1020.640 1000.000 6.0  1020.640 1000.000 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Exterior_Unit3_upper">
                    <gml:name>Wall_between_Unit1_Unit3_Exterior_Unit3_upper</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1020.840 1000.000 3.0 1020.840 1005.030 3.0 1020.840 1005.030 6.0
                        1020.840 1000.000 6.0  1020.840 1000.000 3.0</gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Floor_upper">
                    <gml:name>Wall_between_Unit1_Unit3_Floor_upper</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1020.640 1000.000 3.0 1020.840 1000.00 3.0 1020.840 1005.030 3.0
                        1020.640 1005.030 3.0  1020.640 1000.000 3.0
                      </gml:posList>
                        </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Ceiling_upper">
                    <gml:name>Wall_between_Unit1_Unit3_Ceiling_upper</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1020.640 1000.000 6.0 1020.840 1000.00 6.0 1020.840 1005.030 6.0
                        1020.640 1005.030 6.0  1020.640 1000.000 6.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Side_North_upper">
                    <gml:name>Wall_between_Unit1_Unit3_Side_North_upper</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1020.640 1005.030 3.0 1020.840 1005.030 3.0 1020.840 1005.030 6.0
                        1020.640 1005.030 6.0  1020.640 1005.030 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
```

```
                        </gml:surfaceMember>
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Side_South_upper">
                                <gml:name>Wall_between_Unit1_Unit3_Side_South_upper</gml:name>
                                <gml:exterior>
                                    <gml:LinearRing>
                                        <gml:posList>1020.640 1000.00 3.0 1020.840 1000.00 3.0 1020.840 1000.00 6.0
                                        1020.640 1000.00 6.0 1020.640 1000.00 3.0
                                        </gml:posList>
                                    </gml:LinearRing>
                                </gml:exterior>
                            </gml:Polygon>
                        </gml:surfaceMember>
                    </gml:CompositeSurface>
                </gml:surfaceMember>
            </gml:MultiSurface>
        </bild:representedByMultiSurface>
    </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ====================== Floor_between_Unit1_Unit3  ==========================-->
<bild:consistsOfStructuralComponent>
    <bild:Floor gml:id="DCDM_Floor_between_Unit1_Unit3">
        <bild:representedByMultiSurface>
            <gml:MultiSurface gml:id="DCDM_Floor_between_Unit1-Unit3">
                <gml:surfaceMember>
                    <gml:CompositeSurface gml:id="DCDM_Floor_between-Unit1-Unit3">
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit3_Interior_1">
                                <gml:name>Floor_between_Unit1_Unit3_Interior_1</gml:name>
                                <gml:exterior>
                                    <!-- -->
                                    <gml:LinearRing>
                                        <gml:posList>1020.840 1000.20 2.80 1024.70 1000.20 2.80 1024.70 1005.030 2.80
                                        1020.840 1005.030 2.80 1020.840 1000.20 2.80
                                        </gml:posList>
                                    </gml:LinearRing>
                                </gml:exterior>
                            </gml:Polygon>
                        </gml:surfaceMember>
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit3_Interior_3">
                                <gml:name>Floor_between_Unit1_Unit3_Interior_3</gml:name>
                                <gml:exterior>
                                    <!-- -->
                                    <gml:LinearRing>
                                        <gml:posList>1020.840 1000.20 3.0 1024.70 1000.20 3.0 1024.70 1005.030 3.0
                                        1020.840 1005.030 3.0 1020.840 1000.20 3.0
                                        </gml:posList>
                                    </gml:LinearRing>
                                </gml:exterior>
                            </gml:Polygon>
                        </gml:surfaceMember>
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit3_North">
                                <gml:name>Floor_between_Unit1_Unit3_North</gml:name>
                                <gml:exterior>
                                    <gml:LinearRing>
                                        <gml:posList>1020.840 1005.030 2.80 1024.70 1005.030 2.80 1024.70 1005.030 3.0
                                        1020.840 1005.030 3.0  1020.840 1005.030 2.80
                                        </gml:posList>
                                    </gml:LinearRing>
                                </gml:exterior>
                            </gml:Polygon>
                        </gml:surfaceMember>
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit3_South">
                                <gml:name>Floor_between_Unit1_Unit3_South</gml:name>
                                <gml:exterior>
                                    <gml:LinearRing>
                                        <gml:posList>1020.840 1000.20 2.80 1024.70 1000.20 2.80 1024.70 1000.20 3.0
                                        1020.840 1000.20 3.0  1020.840 1000.20 2.80
                                        </gml:posList>
```

```xml
                    </gml:LinearRing>
                  </gml:exterior>
                </gml:Polygon>
              </gml:surfaceMember>
              <gml:surfaceMember>
                <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit3_Side_Right">
                  <gml:name>Floor_between_Unit1_Unit3_Side_Right</gml:name>
                  <gml:exterior>
                    <gml:LinearRing>
                      <gml:posList>1024.70 1000.20 2.80 1024.70 1005.030 2.80 1024.70 1005.030 3.0
                      1024.70 1000.20 3.0  1024.70 1000.20 2.80
                      </gml:posList>
                    </gml:LinearRing>
                  </gml:exterior>
                </gml:Polygon>
              </gml:surfaceMember>
              <gml:surfaceMember>
                <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit3_Side_Left">
                  <gml:name>Floor_between_Unit1_Unit3_Side_Left</gml:name>
                  <gml:exterior>
                    <gml:LinearRing>
                      <gml:posList>1020.840 1000.20 2.80 1020.840 1005.030 2.80 1020.840 1005.030 3.0
                      1020.840 1000.20 3.0 1020.840 1000.20 2.80
                      </gml:posList>
                    </gml:LinearRing>
                  </gml:exterior>
                </gml:Polygon>
              </gml:surfaceMember>
            </gml:CompositeSurface>
          </gml:surfaceMember>
        </gml:MultiSurface>
      </bild:representedByMultiSurface>
    </bild:Floor>
  </bild:consistsOfStructuralComponent>
  <!-- ============================ Floor_Unit1_Level2  ============================-->
  <bild:consistsOfStructuralComponent>
    <bild:Floor gml:id="DCDM_Floor_Unit1_Level2">
      <bild:representedByMultiSurface>
        <gml:MultiSurface gml:id="DCDM_Floor_Unit1-Level2">
          <gml:surfaceMember>
            <gml:CompositeSurface gml:id="DCDM_Floor-Unit1-Level2">
              <gml:surfaceMember>
                <gml:Polygon gml:id="GML_Floor_Unit1_Level2_Exterior">
                  <gml:name>Floor_Unit1_Level2_Exterior</gml:name>
                  <gml:exterior>
                    <!-- -->
                    <gml:LinearRing>
                      <gml:posList>1000.20 1000.20 3.0 1000.630 1000.20 3.0 1000.655 1004.930 3.0
                      1000.20 1004.930 3.0 1000.20 1000.20 3.0
                      </gml:posList>
                    </gml:LinearRing>
                  </gml:exterior>
                </gml:Polygon>
              </gml:surfaceMember>
              <gml:surfaceMember>
                <gml:Polygon gml:id="GML_Floor_Unit1_Level2_Interior">
                  <gml:name>Floor_Unit1_Level2_Interior</gml:name>
                  <gml:exterior>
                    <!-- -->
                    <gml:LinearRing>
                      <gml:posList>1000.20 1000.20 3.20 1000.630 1000.20 3.20 1000.655 1004.930 3.20
                      1000.20 1004.930 3.20 1000.20 1000.20 3.20
                      </gml:posList>
                    </gml:LinearRing>
                  </gml:exterior>
                </gml:Polygon>
              </gml:surfaceMember>
              <gml:surfaceMember>
                <gml:Polygon gml:id="GML_Floor_Unit1_Level2_North">
                  <gml:name>Floor_Unit1_Level2_North</gml:name>
                  <gml:exterior>
                    <gml:LinearRing>
```

```xml
                    <gml:posList>1000.20 1004.930 3.20 1000.655 1004.930 3.20 1000.655 1004.930 3.0
                    1000.20 1004.930 3.0 1000.20 1004.930 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_Unit1_Level2_South">
                <gml:name>Floor_Unit1_Level2_South</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.20 1000.20 3.20 1000.655 1000.20 3.20 1000.655 1000.20 3.0
                    1000.20 1000.20 3.0 1000.20 1000.20 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_Unit1_Level2_Side_Right">
                <gml:name>Floor_Unit1_Level2_Side_Right</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1004.930 3.20 1000.630 1000.20 3.20 1000.630 1000.20 3.0
                    1000.655 1004.930 3.0 1000.655 1004.930 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_Unit1_Level2_Side_Left">
                <gml:name>Floor_Unit1_Level2_Side_Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.20 1004.930 3.20 1000.20 1000.20 3.20 1000.20 1000.20 3.0
                    1000.20 1004.930 3.0 1000.20 1004.930 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- =========================== Wall_Unit1_Left (Level1)  ==================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_Unit1_Side_Left_Level1">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_Unit1_Side_Left-Level1">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_Unit1_Side-Left-Level1">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Interior_Level1">
                <gml:name>Wall_Unit1_Side-Left_Interior_Level1</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.855 1004.930 0.10 1000.830 1000.20 0.10 1000.830 1000.20 3.20
                    1000.855 1004.930 3.20 1000.855 1004.930 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Exterior_Level1">
                <gml:name>Wall_Unit1_Side-Left_Exterior_Level1</gml:name>
```

```
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.655 1004.930 0.10 1000.630 1000.20 0.10 1000.630 1000.20 3.20
                    1000.655 1004.930 3.20 1000.655 1004.930 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Floor_Level1">
                <gml:name>Wall_Unit1_Side-Left_Floor_Level1</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1004.930 0.10 1000.855 1004.930 0.10 1000.830 1000.20
                    0.10 1000.630 1000.20 0.10 1000.655 1004.930 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Ceiling_Level1">
                <gml:name>Wall_Unit1_Side-Left_Ceiling_Level1</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1004.930 3.20 1000.855 1004.930 3.20 1000.830 1000.20
                    3.20 1000.630 1000.20 3.20 1000.655 1004.930 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_North_Level1">
                <gml:name>Wall_Unit1_Side-Left_North_Level1</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1004.930 0.10 1000.855 1004.930 0.10 1000.855 1004.930
                    3.20 1000.655 1004.930 3.20 1000.655 1004.930 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_South_Level1">
                <gml:name>Wall_Unit1_Side-Left_South_Level1</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.630 1000.20 0.10 1000.830 1000.20 0.10 1000.830 1000.20 3.20
                    1000.630 1000.20 3.20 1000.630 1000.20 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ========================= Wall_Unit1_Left (Level2)  ========================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_Unit1_Side_Left_Level2">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_Unit1_Side_Left-Level2">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_Unit1_Side-Left-Level2">
            <gml:surfaceMember>
```

```xml
        <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Interior_Level2">
          <gml:name>Wall_Unit1_Side-Left_Interior_Level2</gml:name>
          <gml:exterior>
            <!-- -->
            <gml:LinearRing>
              <gml:posList>1000.20 1004.930 3.0 1000.20 1000.20 3.0 1000.20 1000.20 6.0
              1000.20 1004.930 6.0 1000.20 1004.930 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Exterior_Level2">
          <gml:name>Wall_Unit1_Side-Left_Exterior_Level2</gml:name>
          <gml:exterior>
            <!-- -->
            <gml:LinearRing>
              <gml:posList>1000.00 1004.930 3.0 1000.00 1000.20 3.0 1000.00 1000.20 6.0
              1000.00 1004.930 6.0 1000.00 1004.930 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Floor_Level2">
          <gml:name>Wall_Unit1_Side-Left_Floor_Level2</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.00 1004.930 3.0 1000.20 1004.930 3.0 1000.20 1000.20 3.0
              1000.00 1000.20 3.0 1000.00 1004.930 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Ceiling_Level2">
          <gml:name>Wall_Unit1_Side-Left_Ceiling_Level2</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.00 1004.930 6.0 1000.20 1004.930 6.0 1000.20 1000.20 6.0
              1000.00 1000.20 6.0 1000.00 1004.930 6.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_North_Level2">
          <gml:name>Wall_Unit1_Side-Left_North_Level2</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.00 1004.930 3.0 1000.20 1004.930 3.0 1000.20 1004.930 6.0
              1000.00 1004.930 6.0 1000.00 1004.930 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_South_Level2">
          <gml:name>Wall_Unit1_Side-Left_South_Level2</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.00 1000.20 3.0 1000.20 1000.20 3.0 1000.20 1000.20 6.0 1000.00
              1000.20 6.0 1000.00 1000.20 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
```

```xml
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ======================== Ceiling_Unit1 (Level2)  ===========================-->
<bild:consistsOfStructuralComponent>
  <bild:Ceiling gml:id="DCDM_Ceiling_Unit1">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Ceiling-Unit1">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM-Ceiling-Unit1">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit1_Interior">
                <gml:name>Wall_Ceiling_Unit1_Interior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.20 1004.930 5.80 1000.20 1000.20 5.80 1020.640 1000.20 5.80
                    1020.640 1004.930 5.80 1000.20 1004.930 5.80
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit1_Exterior">
                <gml:name>Ceiling_Unit1_Exterior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.20 1004.930 6.0 1000.20 1000.20 6.0 1020.640 1000.20 6.0
                    1020.640 1004.930 6.0 1000.20 1004.930 6.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit1_Side-Left">
                <gml:name>Ceiling_Unit1_Side-Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.20 1004.930 5.80 1000.20 1000.20 5.80 1000.20 1000.20 6.0
                    1000.20 1004.930 6.0 1000.20 1004.930 5.80
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit1_Side-Right">
                <gml:name>Ceiling_Unit1_Side-Right</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.640 1000.20 5.80 1020.640 1004.930 5.80 1020.640 1004.930 6.0
                    1020.640 1000.20 6.0 1020.640 1000.20 5.80
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit1_North">
                <gml:name>Ceiling_Unit1_North</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.20 1004.930 5.80 1020.640 1004.930 5.80 1020.640 1004.930 6.0
                    1000.20 1004.930 6.0 1000.20 1004.930 5.80
                    </gml:posList>
```

```xml
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Ceiling_Unit1_South">
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              <gml:LinearRing>
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                1000.20 1000.20 6.0 1000.20 1000.20 5.80
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
      </gml:CompositeSurface>
    </gml:surfaceMember>
  </gml:MultiSurface>
</bild:representedByMultiSurface>
</bild:Ceiling>
</bild:consistsOfStructuralComponent>
<!-- ======================== Space_Unit1 ======================================-->
<bild:consistsOfSpace>
  <bild:Space gml:id="DCDM-Space-Unit-1">
    <bild:representedBySolid>
      <gml:Solid gml:id="DCDM_Space_Unit_1">
        <gml:exterior>
          <gml:Shell>
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM_Space_Unit-1">
                <!--  Floor_Unit_1  -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_UNIT_1_Floor_Interior_legal">
                    <gml:name>UNIT_1_Floor_Interior</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1000.630 1000.000 0 1000.655 1005.030 0  1024.70 1005.030 0
                        1024.70 1000.000 0 1000.630 1000.000 0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <!--  Wall_South_Unit_1  -->
                <gml:surfaceMember>
                  <gml:CompositeSurface gml:id="GML_UNIT_1_Wall_South_Exterior-legal">
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_UNIT_1_Wall_South_Exterior_legal">
                        <gml:name>UNIT_1_Floor_South_Exterior</gml:name>
                        <gml:exterior>
                          <gml:LinearRing>
                            <gml:posList>1024.70 1000.00 0 1024.70 1000.00 3.00 1020.640 1000.00
                            3.00 1020.640 1000.00 6.00 1000.00 1000.00 6.00 1000.00 1000.00 3.00
                            1000.630 1000.000 3.00 1000.630 1000.000 0 1024.70 1000.00 0
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                  </gml:CompositeSurface>
                </gml:surfaceMember>
                <!--  Wall_North_Unit_1  -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_UNIT_1_Wall_North_Exterior_legal">
                    <gml:name>UNIT_1_Floor_North_Exterior</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1024.70 1005.030 0 1000.655 1005.030 0 1000.655 1005.030 3.00
                        1000.00 1005.030 3.00 1000.00 1005.030 6.00 1020.640 1005.030 6.00 1020.640
                        1005.030 3.00 1024.70 1005.030 3.00 1024.70 1005.030 0
```

```
                </gml:posList>
            </gml:LinearRing>
        </gml:exterior>
    </gml:Polygon>
</gml:surfaceMember>
<!--  Wall_between_Unit1_Unit3_lower -->
<gml:surfaceMember>
    <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Interior_Unit1_lower_legal">
        <gml:name>Wall_between_Unit1_Unit3_Interior_Unit1_lower</gml:name>
        <gml:exterior>
            <!-- -->
            <gml:LinearRing>
                <gml:posList>1024.700 1000.000 0 1024.700 1005.030 0 1024.700 1005.030 3.0
                1024.700 1000.000 3.0  1024.700 1000.000 0
                </gml:posList>
            </gml:LinearRing>
        </gml:exterior>
    </gml:Polygon>
</gml:surfaceMember>
<!--  Wall_between_Unit1_Unit3_upper  -->
<gml:surfaceMember>
    <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit3_Interior_Unit1_upper_legal">
        <gml:name>Wall_between_Unit1_Unit3_Interior_Unit1_upper</gml:name>
        <gml:exterior>
            <!-- -->
            <gml:LinearRing>
                <gml:posList>1020.640 1000.000 3.0 1020.640 1005.030 3.0 1020.640 1005.030
                6.0 1020.640 1000.000 6.0  1020.640 1000.000 3.0
                </gml:posList>
            </gml:LinearRing>
        </gml:exterior>
    </gml:Polygon>
</gml:surfaceMember>
<!--  Floor_between_Unit1_Unit3  -->
<gml:surfaceMember>
    <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit3_Interior_1_legal">
        <gml:name>Floor_between_Unit1_Unit3_Interior_1</gml:name>
        <gml:exterior>
            <!-- -->
            <gml:LinearRing>
                <gml:posList>1020.640 1000.00 3.0 1024.70 1000.00 3.0 1024.70 1005.030 3.0
                1020.640 1005.030 3.0 1020.640 1000.00 3.0
                </gml:posList>
            </gml:LinearRing>
        </gml:exterior>
    </gml:Polygon>
</gml:surfaceMember>
<!--  Floor_Unit1_Level2  -->
<gml:surfaceMember>
    <gml:Polygon gml:id="GML_Floor_Unit1_Level2_Exterior_legal">
        <gml:name>Floor_Unit1_Level2_Exterior</gml:name>
        <gml:exterior>
            <!-- -->
            <gml:LinearRing>
                <gml:posList>1000.630 1000.00 3.0 1000.00 1000.0 3.0 1000.00 1005.030 3.0
                1000.655 1005.030 3.0 1000.630 1000.00 3.0
                </gml:posList>
            </gml:LinearRing>
        </gml:exterior>
    </gml:Polygon>
</gml:surfaceMember>
<!--  Wall_Unit1_Side_Left_Level1  -->
<gml:surfaceMember>
    <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Exterior_Level1_legal">
        <gml:name>Wall_Unit1_Side-Left_Exterior_Level1</gml:name>
        <gml:exterior>
            <!-- -->
            <gml:LinearRing>
                <gml:posList>1000.655 1005.030 0 1000.630 1000.00 0 1000.630 1000.00 3.0
                1000.655 1005.030 3.0 1000.655 1005.030 0
                </gml:posList>
            </gml:LinearRing>
```

```
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <!--  Wall_Unit1_Side_Left_Level2  -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_Unit1_Side-Left_Exterior_Level2_legal">
                    <gml:name>Wall_Unit1_Side-Left_Exterior_Level2</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1000.00 1005.030 3.0 1000.00 1000.00 3.0 1000.00 1000.00 6.0
                        1000.00 1005.030 6.0 1000.00 1005.030 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <!--  Ceiling_Unit1  -->
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Ceiling_Unit1_Exterior_legal">
                    <gml:name>Ceiling_Unit1_Exterior</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1000.00 1005.030 6.0 1000.00 1000.00 6.0 1020.640 1000.00 6.0
                        1020.640 1005.030 6.0 1000.00 1005.030 6.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:Shell>
        </gml:exterior>
      </gml:Solid>
    </bild:representedBySolid>
  </bild:Space>
</bild:consistsOfSpace>
</bild:Unit>
</bild:consistsOfBuildingPart>
<!-- ============================ EndOfUnit1 ======================================-->
<!-- ================================= Unit2  ======================================-->
<bild:consistsOfBuildingPart>
  <bild:Unit gml:id="DCDM_Unit_2" landUse="residential" lpoRef="LOT-2">
    <!-- ==================== UNIT_2's Legal Counterpart  ==============================-->
    <lpo>
      <lpo:LegalPropertyObject gml:id="LOT-2" lpoClass="lot" lpoUnit="single" lpoFormat="3DParcel"
      name="LOT-2" lpoState="created" rrr="ownership" lotEntitlement="35" lotLiability="35">
        <lpo:address>
          <lpo:Address flatNumber="2" propertyNumber="143" streetName="Nicholson" streetType="street"
          Suburb="Footscray" postCode="3011" state="VIC" country="Australia"/>
        </lpo:address>
        <lpo:proprietor>
          <ownr:InterestHolder gml:id="ID_102" pName="Jude Sammonds" share="100" type="person"/>
        </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_2">
    </lpo:representedBySolid>
      </lpo:LegalPropertyObject>
```

```
</lpo>
<!-- ========================== PhysicalPropertyObject ============================-->
<!-- ============================== Floor-Unit2 ================================-->
<bild:consistsOfStructuralComponent>
  <bild:Floor gml:id="DCDM_Floor_Unit_2">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Floor_Unit-2">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Floor-Unit-2">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Floor_Interior">
                <gml:name>UNIT_2_Floor_Interior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1005.030 0.100 1024.70 1005.030 0.100 1024.70 1010.060
                    0.100 1000.655 1010.060 0.100 1000.655 1005.030 0.100
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Floor_Exterior">
                <gml:name>UNIT_2_Floor_Exterior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1005.030 0 1024.70 1005.030 0 1024.70 1010.060 0 1000.655
                    1010.060 0 1000.655 1005.030 0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Floor_Side_South">
                <gml:name>UNIT_2_Floor_Side_South</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1005.030 0 1024.70 1005.030 0 1024.70 1005.030 0.100
                    1000.655 1005.030 0.100 1000.655 1005.030 0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Floor_Side_North">
                <gml:name>UNIT_2_Floor_Side_North</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1010.060 0 1024.70 1010.060 0 1024.70 1010.060 0.100
                    1000.655 1010.060 0.100 1000.655 1010.060 0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Floor_Side_Right">
                <gml:name>UNIT_2_Floor_Side_Right</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1005.030 0 1024.70 1010.060 0 1024.70 1010.060 0.100
                    1024.70 1005.030 0.100 1024.70 1005.030 0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Floor_Side_Left">
                <gml:name>UNIT_2_Floor_Side_Left</gml:name>
```

```xml
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1005.030 0 1000.655 1010.060 0 1000.655 1010.060 0.100
                    1000.655 1005.030 0.100 1000.655 1005.030 0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ======================= Wall-South-Unit2  ===========================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_South_Unit_2">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_South_Unit-2">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_South-Unit-2">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Interior">
                <gml:name>UNIT_2_Wall_South_Interior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1005.130 0.100 1024.70 1005.130 3.00 1020.640 1005.130
                    3.00 1020.640 1005.130 6.00 1000.00 1005.130 6.00 1000.00 1005.130 3.00 1000.655
                    1005.130 3.00 1000.655 1005.130 0.10 1024.70 1005.130 0.100
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Exterior">
                <gml:name>UNIT_2_Floor_South_Exterior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1005.030 0.100 1024.70 1005.030 3.00 1020.640 1005.030
                    3.00 1020.640 1005.030 6.00 1000.00 1005.030 6.00 1000.00 1005.030 3.00 1000.655
                    1005.030 3.00 1000.655 1005.030 0.10 1024.70 1005.030 0.100
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Upper_1">
                <gml:name>UNIT_2_Wall_South_Upper</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1005.030 3.00 1024.70 1005.130 3.00 1020.640 1005.130 3.00
                    1020.640 1005.030 3.00 1024.70 1005.030 3.00
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Upper_2">
                <gml:name>UNIT_2_Wall_South_Upper</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.640 1005.130 3.00 1020.640 1005.130 6.00 1020.640 1005.030
                    6.00 1020.640 1005.030 3.00 1020.640 1005.130 3.00
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
```

```
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Upper_3">
    <gml:name>UNIT_2_Wall_South_Upper</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1020.640 1005.130 6.00 1000.00 1005.130 6.00 1000.00 1005.030 6.00
        1020.640 1005.030 6.00 1020.640 1005.130 6.00
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Lower">
    <gml:name>UNIT_2_Wall_South_Lower</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1000.655 1005.030 0.10 1024.70 1005.030 0.10 1024.70 1005.130 0.10
        1000.655 1005.130 0.10 1000.655 1005.030 0.10
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Side_Right">
    <gml:name>UNIT_2_Wall_South_Side_Right</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1024.70 1005.030 0.10 1024.70 1005.130 0.10 1024.70 1005.130 3.0
        1024.70 1005.030 3.0 1024.70 1005.030 0.10
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Side_Left_1">
    <gml:name>UNIT_2_Wall_South_Side_Left</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1000.655 1005.030 0.10 1000.655 1005.130 0.10 1000.655 1005.130
        3.0 1000.655 1005.030 3.0 1000.655 1005.030 0.10
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Side_Left_2">
    <gml:name>UNIT_2_Wall_South_Side_Left</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1000.00 1005.030 3 1000.655 1005.030 3.0 1000.655 1005.130 3.0
        1000.00 1005.130 3.0 1000.00 1005.030 3
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Side_Left_3">
    <gml:name>UNIT_2_Wall_South_Side_Left</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1000.00 1005.030 3 1000.00 1005.130 3.0 1000.00 1005.130 6.0
        1000.00 1005.030 6.0 1000.00 1005.030 3
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
```

```xml
                </gml:CompositeSurface>
              </gml:surfaceMember>
            </gml:MultiSurface>
          </bild:representedByMultiSurface>
        </bild:Wall>
      </bild:consistsOfStructuralComponent>
      <!-- ======================== Wall-North-Unit2  ================================-->
      <bild:consistsOfStructuralComponent>
        <bild:Wall gml:id="DCDM_Wall_North_Unit_2">
          <bild:representedByMultiSurface>
            <gml:MultiSurface gml:id="DCDM_Wall_North_Unit-2">
              <gml:surfaceMember>
                <gml:CompositeSurface gml:id="DCDM_Wall_North-Unit-2">
                  <gml:surfaceMember>
                    <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Interior">
                      <gml:name>UNIT_2_Wall_North_Interior</gml:name>
                      <gml:exterior>
                        <!-- -->
                        <gml:LinearRing>
                          <gml:posList>1024.70 1009.830 0.100 1024.70 1009.830 3.00 1020.640 1009.830
                          3.00 1020.640 1009.830 6.00 1000.00 1009.830 6.00 1000.00 1009.830 3.00 1000.655
                          1009.830 3.00 1000.655 1009.830 0.10 1024.70 1009.830 0.100
                          </gml:posList>
                        </gml:LinearRing>
                      </gml:exterior>
                    </gml:Polygon>
                  </gml:surfaceMember>
                  <gml:surfaceMember>
                    <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Exterior">
                      <gml:name>UNIT_2_Floor_North_Exterior</gml:name>
                      <gml:exterior>
                        <!-- -->
                        <gml:LinearRing>
                          <gml:posList>1024.70 1010.060 0.100 1024.70 1010.060 3.00 1020.640 1010.060
                          3.00 1020.640 1010.060 6.00 1000.00 1010.060 6.00 1000.00 1010.060 3.00 1000.655
                          1010.060 3.00 1000.655 1010.060 0.10 1024.70 1010.060 0.100
                          </gml:posList>
                        </gml:LinearRing>
                      </gml:exterior>
                    </gml:Polygon>
                  </gml:surfaceMember>
                  <gml:surfaceMember>
                    <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Upper_1">
                      <gml:name>UNIT_2_Wall_North_Upper</gml:name>
                      <gml:exterior>
                        <gml:LinearRing>
                          <gml:posList>1024.70 1009.830 3.00 1024.70 1010.060 3.00 1020.640 1010.060 3.00
                          1020.640 1009.830 3.00 1024.70 1009.830 3.00
                          </gml:posList>
                        </gml:LinearRing>
                      </gml:exterior>
                    </gml:Polygon>
                  </gml:surfaceMember>
                  <gml:surfaceMember>
                    <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Upper_2">
                      <gml:name>UNIT_2_Wall_North_Upper</gml:name>
                      <gml:exterior>
                        <gml:LinearRing>
                          <gml:posList>1020.640 1009.830 3.00 1020.640 1010.060 3.00 1020.640 1010.060
                          6.00 1020.640 1009.830 6.00 1020.640 1009.830 3.00
                          </gml:posList>
                        </gml:LinearRing>
                      </gml:exterior>
                    </gml:Polygon>
                  </gml:surfaceMember>
                  <gml:surfaceMember>
                    <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Upper_3">
                      <gml:name>UNIT_2_Wall_North_Upper</gml:name>
                      <gml:exterior>
                        <gml:LinearRing>
                          <gml:posList>1020.640 1009.830 6.00 1020.640 1010.060 6.00 1000.00 1010.060
                          6.00 1000.00 1009.830 6.00 1020.640 1009.830 6.00
```

```
                </gml:posList>
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          </gml:Polygon>
        </gml:surfaceMember>
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            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1000.655 1009.830 0.10 1024.70 1009.830 0.10 1024.70 1010.060 0.10
                1000.655 1010.060 0.10 1000.655 1009.830 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
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            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.70 1009.830 0.10 1024.70 1010.060 0.10 1024.70 1010.060 3.0
                1024.70 1009.830 3.0 1024.70 1009.830 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Side_Left_1">
            <gml:name>UNIT_2_Wall_North_Side_Left</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1000.655 1009.830 0.10 1000.655 1010.060 0.10 1000.655 1010.060
                3.0 1000.655 1009.830 3.0 1000.655 1009.830 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Side_Left_2">
            <gml:name>UNIT_2_Wall_North_Side_Left</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1000.00 1009.830 3 1000.655 1009.830 3.0 1000.655 1010.060 3.0
                1000.00 1010.060 3.0 1000.00 1009.830 3
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Side_Left_3">
            <gml:name>UNIT_2_Wall_North_Side_Left</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1000.00 1009.830 3.0 1000.00 1010.060 3.0 1000.00 1010.060 6.0
                1000.00 1009.830 6.0 1000.00 1009.830 3
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
      </gml:CompositeSurface>
    </gml:surfaceMember>
  </gml:MultiSurface>
</bild:representedByMultiSurface>
</bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ================== Floor-between-Unit2-Unit3_ lower (0.10)  ========================-->
```

```xml
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    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Floor_between_Unit2_Unit3-Lower">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Floor_between_Unit2-Unit3-Lower">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_between_Unit2_Unit3_Interior">
                <gml:name>Floor_between_Unit2_Unit3_Interior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1005.030 0.100 1024.90 1005.030 0.10 1024.90 1010.060 0.10
                    1024.70 1010.060 0.10 1024.70 1005.030 0.100
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_between_Unit2_Unit3_Exterior">
                <gml:name>Floor_between_Unit2_Unit3_Exterior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1005.030 0 1024.90 1010.060 0 1024.90 1010.060 0 1024.70
                    1005.030 0 1024.70 1005.030 0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_between_Unit2_Unit3_North">
                <gml:name>Floor_between_Unit2_Unit3_North</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1010.060 0 1024.90 1010.060 0 1024.90 1010.060 0.10
                    1024.70 1010.060 0.10 1024.70 1010.060 0
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                  </gml:LinearRing>
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            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_between_Unit2_Unit3_South">
                <gml:name>Floor_between_Unit2_Unit3_South</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.70 1005.030 0.000 1024.900 1005.030 0.000 1024.900 1005.030
                    0.100 1024.70 1005.030 0.100 1024.70 1005.030 0.000
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_between_Unit2_Unit3_Side_Right">
                <gml:name>Floor_between_Unit2_Unit3_Side_Right</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.900 1005.030 0.000 1024.900 1010.060 0.000 1024.900 1010.060
                    0.100 1024.900 1005.030 0.100  1024.900 1005.030 0.000
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_between_Unit2_Unit3_Side_Left">
                <gml:name>Floor_between_Unit2_Unit3_Side_Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
```

```
                        <gml:posList>1024.700 1005.030 0.000 1024.700 1010.060 0.000 1024.700 1010.060
                        0.100 1024.700 1005.030 0.100  1024.700 1005.030 0.000
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Floor>
    </bild:consistsOfStructuralComponent>
    <!-- ==================== Wall_between_Unit2_Unit3_1(lower)  ==========================-->
    <bild:consistsOfStructuralComponent>
      <bild:Wall gml:id="DCDM_Wall_between_Unit2_Unit3_lower">
        <bild:representedByMultiSurface>
          <gml:MultiSurface gml:id="DCDM_Wall_between_Unit2_Unit3-lower">
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM_Wall_between_Unit2-Unit3-lower">
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Interior_Unit2_lower">
                    <gml:name>Wall_between_Unit2_Unit3_Interior_Unit2_lower</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1024.700 1005.030 0.10 1024.700 1010.060 0.10 1024.700 1010.060
                        3.0 1024.700 1005.030 3.0 1024.700 1005.030 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Interior_Unit3_lower">
                    <gml:name>Wall_between_Unit2_Unit3_Interior_Unit3_lower</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1024.900 1005.030 0.10 1024.900 1010.060 0.10 1024.900 1010.060
                        3.0 1024.900 1005.030 3.0  1024.900 1005.030 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Floor_lower">
                    <gml:name>Wall_between_Unit2_Unit3_Floor_lower</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.700 1005.030 0.10 1024.900 1005.030 0.10 1024.900 1010.060
                        0.10 1024.700 1010.060 0.10  1024.700 1005.030 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Ceiling_lower">
                    <gml:name>Wall_between_Unit2_Unit3_Ceiling_lower</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.700 1005.030 3.0 1024.900 1005.030 3.0 1024.900 1010.060 3.0
                        1024.700 1010.060 3.0  1024.700 1005.030 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Side_North_lower">
```

```
                <gml:name>Wall_between_Unit2_Unit3_Side_North_lower</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.700 1010.060 0.10 1024.900 1010.060 0.10 1024.900 1010.060
                    3.0 1024.700 1010.060 3.0  1024.700 1010.060 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Side_South_lower">
                <gml:name>Wall_between_Unit2_Unit3_Side_South_lower</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.700 1005.030 0.10 1024.900 1005.030 0.10 1024.900 1005.030
                    3.0 1024.700 1005.030 3.0  1024.700 1005.030 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- =================== Wall_between_Unit2_Unit3_1(upper)  ========================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_between_Unit2_Unit3_upper">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_between_Unit2_Unit3-upper">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_between_Unit2-Unit3-upper">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Interior_Unit2_upper">
                <gml:name>Wall_between_Unit2_Unit3_Interior_Unit2_upper</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.640 1005.030 3.0 1020.640 1010.060 3.0 1020.640 1010.060 6.0
                    1020.640 1005.030 6.0  1020.640 1005.030 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Exterior_Unit3_upper">
                <gml:name>Wall_between_Unit2_Unit3_Exterior_Unit3_upper</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.840 1005.030 3.0 1020.840 1010.060 3.0 1020.840 1010.060 6.0
                    1020.840 1005.030 6.0  1020.840 1005.030 3.0</gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Floor_upper">
                <gml:name>Wall_between_Unit2_Unit3_Floor_upper</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.640 1005.030 3.0 1020.840 1005.030 3.0 1020.840 1010.060 3.0
                    1020.640 1010.060 3.0  1020.640 1005.030 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
```

```
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Ceiling_upper">
    <gml:name>Wall_between_Unit2_Unit3_Ceiling_upper</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1020.640 1005.030 6.0 1020.840 1005.030 6.0 1020.840 1010.060 6.0
        1020.640 1010.060 6.0  1020.640 1005.030 6.0
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Side_North_upper">
    <gml:name>Wall_between_Unit2_Unit3_Side_North_upper</gml:name>
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1020.640 1010.060 3.0 1020.840 1010.060 3.0 1020.840 1010.060 6.0
        1020.640 1010.060 6.0  1020.640 1010.060 3.0
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
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    <gml:exterior>
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        <gml:posList>1020.640 1005.030 3.0 1020.840 1005.030 3.0 1020.840 1005.030 6.0
        1020.640 1005.030 6.0 1020.640 1005.030 3.0
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
</gml:CompositeSurface>
</gml:surfaceMember>
</gml:MultiSurface>
</bild:representedByMultiSurface>
</bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ======================== Floor_between_Unit2_Unit3  ========================-->
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  <bild:Floor gml:id="DCDM_Floor_between_Unit2_Unit3">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Floor_between_Unit2-Unit3">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Floor_between-Unit2-Unit3">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit2_Unit3_Interior_1">
                <gml:name>Floor_between_Unit2_Unit3_Interior_1</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.840 1005.030 2.80 1024.70 1005.030 2.80 1024.70 1009.830 2.80
                    1020.840 1009.830 2.80 1020.840 1005.030 2.80
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                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit2_Unit3_Interior_3">
                <gml:name>Floor_between_Unit2_Unit3_Interior_3</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.840 1005.030 3.0 1024.70 1005.030 3.0 1024.70 1009.830 3.0
                    1020.840 1009.830 3.0 1020.840 1005.030 3.0
                    </gml:posList>
                  </gml:LinearRing>
```

```xml
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
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                <gml:exterior>
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                    1020.840 1009.830 3.0  1020.840 1009.830 2.80
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
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                  <gml:LinearRing>
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              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit2_Unit3_Side_Right">
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                <gml:exterior>
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                    <gml:posList>1024.70 1005.030 2.80 1024.70 1009.830 2.80 1024.70 1009.830 3.0
                    1024.70 1005.030 3.0  1024.70 1005.030 2.80
                    </gml:posList>
                  </gml:LinearRing>
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              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit2_Unit3_Side_Left">
                <gml:name>Floor_between_Unit2_Unit3_Side_Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1005.030 2.80 1020.840 1009.830 2.80 1020.840 1009.830
                    3.0 1020.840 1005.030 3.0 1020.840 1005.030 2.80
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ======================== Floor_Unit2_Level2  ================================-->
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  <bild:Floor gml:id="DCDM_Floor_Unit2_Level2">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Floor_Unit2-Level2">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Floor-Unit2-Level2">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_Unit2_Level2_Exterior">
                <gml:name>Floor_Unit2_Level2_Exterior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.20 1005.130 3.0 1000.655 1005.130 3.0 1000.655 1009.830 3.0
                    1000.20 1009.830 3.0 1000.20 1005.130 3.0
```

```xml
                    </gml:posList>
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                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
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                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
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                    3.20 1000.20 1009.830 3.20 1000.20 1005.130 3.20
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                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
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                <gml:exterior>
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                    1000.20 1009.830 3.0 1000.20 1009.830 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
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                <gml:exterior>
                  <gml:LinearRing>
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                  </gml:LinearRing>
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              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
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                <gml:name>Floor_Unit2_Level2_Side_Right</gml:name>
                <gml:exterior>
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                    <gml:posList>1000.655 1005.130 3.20 1000.655 1009.830 3.20 1000.655 1009.830
                    3.0 1000.655 1005.130 3.0 1000.655 1005.130 3.20
                    </gml:posList>
                  </gml:LinearRing>
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            </gml:surfaceMember>
            <gml:surfaceMember>
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                <gml:exterior>
                  <gml:LinearRing>
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                    1000.20 1005.130 3.0 1000.20 1005.130 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Floor>
</bild:consistsOfStructuralComponent>
```

```xml
<!-- =================== Wall_Unit2_Left (Level1)  ================================-->
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  <bild:Wall gml:id="DCDM_Wall_Unit2_Side_Left_Level1">
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            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_Interior_Level1">
                <gml:name>Wall_Unit2_Side-Left_Interior_Level1</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.855 1009.830 0.10 1000.855 1005.130 0.10 1000.855 1005.130
                    3.20 1000.855 1009.830 3.20 1000.855 1009.830 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
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                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.655 1009.830 0.10 1000.655 1005.130 0.10 1000.655 1005.130
                    3.20 1000.655 1009.830 3.20 1000.655 1009.830 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_Floor_Level1">
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                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1009.830 0.10 1000.855 1009.830 0.10 1000.855 1005.130
                    0.10 1000.655 1005.130 0.10 1000.655 1009.830 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
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                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1009.830 3.20 1000.855 1009.830 3.20 1000.855 1005.130
                    3.20 1000.655 1005.130 3.20 1000.655 1009.830 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_North_Level1">
                <gml:name>Wall_Unit2_Side-Left_North_Level1</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.655 1009.830 0.10 1000.855 1009.830 0.10 1000.855 1009.830
                    3.20 1000.655 1009.830 3.20 1000.655 1009.830 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
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```

```xml
                    <gml:exterior>
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                        3.20 1000.630 1005.130 3.20 1000.630 1005.130 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Wall>
    </bild:consistsOfStructuralComponent>
    <!-- ================ Wall_Unit2_Left (Level2)  ================================-->
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          <gml:MultiSurface gml:id="DCDM_Wall_Unit2_Side_Left-Level2">
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM_Wall_Unit2_Side-Left-Level2">
                <gml:surfaceMember>
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                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1000.20 1009.830 3.0 1000.20 1005.130 3.0 1000.20 1005.130 6.0
                        1000.20 1009.830 6.0 1000.20 1009.830 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
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                    <gml:name>Wall_Unit2_Side-Left_Exterior_Level2</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
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                        1000.00 1009.830 6.0 1000.00 1009.830 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_Floor_Level2">
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                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1000.00 1009.830 3.0 1000.20 1009.830 3.0 1000.20 1005.130 3.0
                        1000.00 1005.130 3.0 1000.00 1009.830 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_Ceiling_Level2">
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                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1000.00 1009.830 6.0 1000.20 1009.830 6.0 1000.20 1005.130 6.0
                        1000.00 1005.130 6.0 1000.00 1009.830 6.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
```

```
<gml:surfaceMember>
  <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_North_Level2">
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      <gml:LinearRing>
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        1000.00 1009.830 6.0 1000.00 1009.830 3.0
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMember>
<gml:surfaceMember>
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    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>1000.00 1005.130 3.0 1000.20 1005.130 3.0 1000.20 1005.130 6.0
        1000.00 1005.130 6.0 1000.00 1005.130 3.0
        </gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
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</gml:MultiSurface>
</bild:representedByMultiSurface>
</bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ======================== Ceiling_Unit2 (Level2)  ============================-->
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  <bild:Wall gml:id="DCDM_Ceiling_Unit2">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Ceiling-Unit2">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM-Ceiling-Unit2">
            <gml:surfaceMember>
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                <gml:name>Wall_Ceiling_Unit2_Interior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.20 1009.830 5.80 1000.20 1005.130 5.80 1020.640 1005.130 5.80
                    1020.640 1009.830 5.80 1000.20 1009.830 5.80
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit2_Exterior">
                <gml:name>Ceiling_Unit2_Exterior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1000.20 1009.830 6.0 1000.20 1005.130 6.0 1020.640 1005.130 6.0
                    1020.640 1009.830 6.0 1000.20 1009.830 6.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit2_Side-Left">
                <gml:name>Ceiling_Unit2_Side-Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1000.20 1009.830 5.80 1000.20 1005.130 5.80 1000.20 1005.130 6.0
                    1000.20 1009.830 6.0 1000.20 1009.830 5.80
                    </gml:posList>
                  </gml:LinearRing>
```

```
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Ceiling_Unit2_Side-Right">
                    <gml:name>Ceiling_Unit2_Side-Right</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1020.640 1005.130 5.80 1020.640 1009.830 5.80 1020.640 1009.830
                        6.0 1020.640 1005.130 6.0 1020.640 1005.130 5.80
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Ceiling_Unit2_North">
                    <gml:name>Ceiling_Unit2_North</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1000.20 1009.830 5.80 1020.640 1009.830 5.80 1020.640 1009.830 6.0
                        1000.20 1009.830 6.0 1000.20 1009.830 5.80
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
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                    <gml:name>Ceiling_Unit2_South</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1000.20 1005.130 5.80 1020.640 1005.130 5.80 1020.640 1005.130 6.0
                        1000.20 1005.130 6.0 1000.20 1005.130 5.80
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Wall>
    </bild:consistsOfStructuralComponent>
    <!-- ========================== Space_Unit2 ==============================-->
    <bild:consistsOfSpace>
      <bild:Space gml:id="DCDM-Space-Unit-2">
        <bild:representedBySolid>
          <gml:Solid gml:id="DCDM_Space_Unit_2">
            <gml:exterior>
              <gml:Shell>
                <gml:surfaceMember>
                  <gml:CompositeSurface gml:id="DCDM_Space_Unit-2">
                    <!--  Floor_Unit_2  -->
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_UNIT_2_Floor_Interior_legal">
                        <gml:name>UNIT_2_Floor_Interior</gml:name>
                        <gml:exterior>
                          <gml:LinearRing>
                            <gml:posList>1000.655 1005.030 0 1000.655 1010.060 0  1024.70 1010.060 0
                            1024.70 1005.030 0 1000.655 1005.030 0
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                    <!--  Wall_South_Unit_2  -->
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_UNIT_2_Wall_South_Exterior_legal">
                        <gml:name>UNIT_2_Floor_South_Exterior</gml:name>
                        <gml:exterior>
```

```xml
          <gml:LinearRing>
            <gml:posList>1024.70 1005.030 0 1024.70 1005.030 3.00 1020.640 1005.030
            3.00 1020.640 1005.030 6.00 1000.00 1005.030 6.00 1000.00 1005.030 3.00
            1000.655 1005.030 3.00 1000.655 1005.030 0 1024.70 1005.030 0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!--  Wall_North_Unit_2  -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_UNIT_2_Wall_North_Exterior_legal">
        <gml:name>UNIT_2_Floor_North_Exterior</gml:name>
        <gml:exterior>
          <!-- -->
          <gml:LinearRing>
            <gml:posList>1024.70 1010.060 0 1000.655 1010.060 0 1000.655 1010.060 3.00
            1000.00 1010.060 3.00 1000.00 1010.060 6.00 1020.640 1010.060 6.00 1020.640
            1010.060 3.00 1024.70 1010.060 3.00 1024.70 1010.060 0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!--  Wall_between_Unit2_Unit3_lower  -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Interior_Unit2_lower_legal">
        <gml:name>Wall_between_Unit2_Unit3_Interior_Unit2_lower</gml:name>
        <gml:exterior>
          <!-- -->
          <gml:LinearRing>
            <gml:posList>1024.700 1005.030 0 1024.700 1010.060 0 1024.700 1010.060 3.0
            1024.700 1005.030 3.0  1024.700 1005.030 0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!--  Wall_between_Unit2_Unit3_upper  -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Wall_between_Unit2_Unit3_Interior_Unit2_upper_legal">
        <gml:name>Wall_between_Unit2_Unit3_Interior_Unit2_upper</gml:name>
        <gml:exterior>
          <!-- -->
          <gml:LinearRing>
            <gml:posList>1020.640 1005.030 3.0 1020.640 1010.060 3.0 1020.640 1010.060
            6.0 1020.640 1005.030 6.0  1020.640 1005.030 3.0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!--  Floor_between_Unit2_Unit3  -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Floor_between_Unit2_Unit3_Interior_1_legal">
        <gml:name>Floor_between_Unit2_Unit3_Interior_1</gml:name>
        <gml:exterior>
          <!-- -->
          <gml:LinearRing>
            <gml:posList>1020.640 1005.030 3.0 1024.70 1005.030 3.0 1024.70 1010.060
            3.0 1020.640 1010.060 3.0 1020.640 1005.030 3.0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!--  Floor_Unit2_Level2  -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Floor_Unit2_Level2_Exterior_legal">
        <gml:name>Floor_Unit2_Level2_Exterior</gml:name>
        <gml:exterior>
          <!-- -->
```

```
                          <gml:LinearRing>
                            <gml:posList>1000.00 1005.030 3.0 1000.00 1010.060 3.0 1000.655 1010.060
                            3.0 1000.655 1005.030 3.0 1000.00 1005.030 3.0
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                    <!--  Wall_Unit2_Side_Left_Level1  -->
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_Exterior_Level1_legal">
                        <gml:name>Wall_Unit2_Side-Left_Exterior_Level1</gml:name>
                        <gml:exterior>
                          <!-- -->
                          <gml:LinearRing>
                            <gml:posList>1000.655 1010.060 0 1000.655 1005.030 0 1000.655 1005.030 3.0
                            1000.655 1010.060 3.0 1000.655 1010.060 0
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                    <!--  Wall_Unit2_Side_Left_Level2  -->
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_Wall_Unit2_Side-Left_Exterior_Level2_legal">
                        <gml:name>Wall_Unit2_Side-Left_Exterior_Level2</gml:name>
                        <gml:exterior>
                          <!-- -->
                          <gml:LinearRing>
                            <gml:posList>1000.00 1010.060 3.0 1000.00 1005.030 3.0 1000.00 1005.030 6.0
                            1000.00 1010.060 6.0 1000.00 1010.060 3.0
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                    <!--  Ceiling_Unit2  -->
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_Ceiling_Unit2_Exterior_legal">
                        <gml:name>Ceiling_Unit2_Exterior</gml:name>
                        <gml:exterior>
                          <!-- -->
                          <gml:LinearRing>
                            <gml:posList>1000.00 1010.060 6.0 1000.00 1005.030 6.0 1020.640 1005.030
                            6.0 1020.640 1010.060 6.0 1000.00 1010.060 6.0
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                  </gml:CompositeSurface>
                </gml:surfaceMember>
              </gml:Shell>
            </gml:exterior>
          </gml:Solid>
        </bild:representedBySolid>
      </bild:Space>
    </bild:consistsOfSpace>
  </bild:Unit>
</bild:consistsOfBuildingPart>
<!-- ===================== EndOfUnit2 ========================================-->
<!-- ========================= Unit3 ===========================================-->
<bild:consistsOfBuildingPart>
  <bild:Unit gml:id="DCDM_Unit_3" landUse="residential" lpoRef="LOT-3">
    <!-- ====================== UNIT_3's Legal Counterpart ========================-->
    <lpo>
      <lpo:LegalPropertyObject gml:id="LOT-3" lpoClass="lot" lpoUnit="single" lpoFormat="3DParcel"
      name="LOT-3" lpoState="created" rrr="ownership" lotEntitlement="30" lotLiability="30">
        <lpo:address>
          <lpo:Address flatNumber="3" propertyNumber="143" streetName="Nicholson" streetType="street"
          Suburb="Footscray" postCode="3011" state="VIC" country="Australia"/>
        </lpo:address>
```

```
    <lpo:proprietor>
      <ownr:InterestHolder gml:id="ID_103" pName="Alexander Dave" share="100" type="person"/>
    </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_3">
</lpo:representedBySolid>
  </lpo:LegalPropertyObject>
</lpo>
<!-- ====================== PhysicalPropertyObject  ========================-->
<!-- ============================ Floor-Unit3  ===========================-->
<bild:consistsOfStructuralComponent>
  <bild:Floor gml:id="DCDM_Floor_Unit_3">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Floor_Unit-3">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Floor-Unit-3">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Floor_Interior">
                <gml:name>Unit_3_Floor_Interior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.900 1000.000 0.100 1035.970 1000.000 0.100 1035.970 1010.060
                    0.100 1024.900 1010.060 0.100 1024.900 1000.000 0.100
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Floor_Exterior">
                <gml:name>Unit_3_Floor_Exterior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.900 1000.000 0 1035.970 1000.000  0 1035.970 1010.060  0
                    1024.900 1010.060  0 1024.900 1000.000  0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Floor_Side_South">
                <gml:name>Unit_3_Floor_Side_South</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.900 1000.000 0 1035.970 1000.000  0 1035.970 1000.000  0.10
                    1024.900 1000.000  0.10 1024.900 1000.000  0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Floor_Side_North">
                <gml:name>Unit_3_Floor_Side_North</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.900 1010.060 0 1035.970 1010.060  0 1035.970 1010.060  0.10
                    1024.900 1010.060  0.10 1024.900 1010.060  0
                    </gml:posList>
```

```
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Floor_Side_Right">
                <gml:name>Unit_3_Floor_Side_Right</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1035.970 1000.00 0 1035.970 1010.060  0 1035.970 1010.060  0.10
                    1035.970 1010.060  0.10 1035.970 1000.00  0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Floor_Side_Left">
                <gml:name>Unit_3_Floor_Side_Left</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.900 1000.00 0 1024.900 1010.060  0 1024.900 1010.060  0.10
                    1024.900 1010.060  0.10 1024.900 1000.00  0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Floor>
</bild:consistsOfStructuralComponent>
<!-- ========================== Wall-South-Unit3  ==========================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_South_Unit_3">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_South_Unit-3">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_South-Unit-3">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_South_Interior">
                <gml:name>Unit_3_Wall_South_Interior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1000.20 3.0 1024.900 1000.20 3.00 1024.900 1000.20 0.10
                    1035.770 1000.20 0.10 1035.770 1000.20 6.00 1020.840 1000.20 6.0 1020.840
                    1000.20 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_South_Exterior">
                <gml:name>Unit_3_Floor_South_Exterior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1000.00 3.0 1024.900 1000.00 3.00 1024.900 1000.00 0.10
                    1035.770 1000.00 0.10 1035.770 1000.00 6.00 1020.840 1000.00 6.0 1020.840
                    1000.00 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_South_Upper">
                <gml:name>Unit_3_Wall_South_Upper</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
```

```xml
                <gml:posList>1020.840 1000.00 6.0 1035.770 1000.00 6.0 1035.770 1000.20 6.00
                1020.840 1000.200 6.00 1020.840 1000.00 6.00
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Unit_3_Wall_South_Lower_1">
            <gml:name>Unit_3_Wall_South_Lower_1</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1020.840 1000.00 3.0 1024.900 1000.00 3.0 1024.900 1000.20 3.0
                1020.840 1000.200 3.0 1020.840 1000.00 3.0
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Unit_3_Wall_South_Lower_2">
            <gml:name>Unit_3_Wall_South_Lower_2</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.900 1000.00 3.0 1024.900 1000.00 0.10 1024.900 1000.200 0.10
                1024.900 1000.200 3.0 1024.900 1000.00 3.0
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Unit_3_Wall_South_Lower_3">
            <gml:name>Unit_3_Wall_South_Lower_3</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1024.900 1000.00 0.10 1035.770 1000.00 0.10 1035.770 1000.200 0.10
                1024.900 1000.200 0.10 1024.900 1000.00 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Unit_3_Wall_South_Side_Right">
            <gml:name>Unit_3_Wall_South_Side_Right</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1035.770 1000.00 0.10 1035.770 1000.20 0.10 1035.770 1000.200 6.0
                1035.770 1000.00 6.0 1035.770 1000.00 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Unit_3_Wall_South_Side_Left_1">
            <gml:name>Unit_3_Wall_South_Side_Left</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1020.840 1000.00 3.0 1020.840 1000.20 3.0 1020.840 1000.200 6.0
                1020.840 1000.00 6.0 1020.840 1000.00 3.0
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
      </gml:CompositeSurface>
    </gml:surfaceMember>
  </gml:MultiSurface>
 </bild:representedByMultiSurface>
</bild:Wall>
```

```
</bild:consistsOfStructuralComponent>
<!-- ======================= Wall-North-Unit3 ==================================-->
<bild:consistsOfStructuralComponent>
  <bild:Wall gml:id="DCDM_Wall_North_Unit_3">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Wall_North_Unit-3">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Wall_North-Unit-3">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_North_Interior">
                <gml:name>Unit_3_Wall_North_Interior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1009.830 3.0 1024.900 1009.830 3.00 1024.900 1009.830
                    0.10 1035.770 1009.830 0.10 1035.770 1009.830 6.00 1020.840 1009.830 6.0
                    1020.840 1009.830 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_North_Exterior">
                <gml:name>Unit_3_Floor_North_Exterior</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1010.060 3.0 1024.900 1010.060 3.00 1024.900 1010.060
                    0.10 1035.770 1010.060 0.10 1035.770 1010.060 6.00 1020.840 1010.060 6.0
                    1020.840 1010.060 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_North_Upper">
                <gml:name>Unit_3_Wall_North_Upper</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1009.830 6.0 1035.770 1009.830 6.0 1035.770 1010.060 6.00
                    1020.840 1010.060 6.00 1020.840 1009.830 6.00
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_North_Lower_1">
                <gml:name>Unit_3_Wall_North_Lower_1</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1009.830 3.0 1024.900 1009.830 3.0 1024.900 1010.060 3.0
                    1020.840 1010.060 3.0 1020.840 1009.830 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_North_Lower_2">
                <gml:name>Unit_3_Wall_North_Lower_2</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1024.900 1009.830 3.0 1024.900 1009.830 0.10 1024.900 1010.060
                    0.10 1024.900 1010.060 3.0 1024.900 1009.830 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Unit_3_Wall_North_Lower_3">
```

```
                    <gml:name>Unit_3_Wall_North_Lower_3</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.900 1009.830 0.10 1035.770 1009.830 0.10 1035.770 1010.060
                        0.10 1024.900 1010.060 0.10 1024.900 1009.830 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Unit_3_Wall_North_Side_Right">
                    <gml:name>Unit_3_Wall_North_Side_Right</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1035.770 1009.830 0.10 1035.770 1010.060 0.10 1035.770 1010.060
                        6.0 1035.770 1009.830 6.0 1035.770 1009.830 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Unit_3_Wall_North_Side_Left_1">
                    <gml:name>Unit_3_Wall_North_Side_Left</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1020.840 1009.830 3.0 1020.840 1010.060 3.0 1020.840 1010.060 6.0
                        1020.840 1009.830 6.0 1020.840 1009.830 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Wall>
    </bild:consistsOfStructuralComponent>
    <!-- =============== Floor-between-Unit1-Unit2-Unit3 (lower) ==========================-->
    <bild:consistsOfStructuralComponent>
      <bild:Floor gml:id="DCDM_Floor_between_Unit1_Unit2_Unit3">
        <bild:representedByMultiSurface>
          <gml:MultiSurface gml:id="DCDM_Floor_between_Unit1_Unit2-Unit3">
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM_Floor_between_Unit1-Unit2-Unit3">
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_between_Unit1_Unit2_Unit3_Floor">
                    <gml:name>Floor_between_Unit1_Unit2_Unit3_Floor</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.70 1000.00 0.100 1024.90 1000.00 0.10 1024.90 1010.060 0.10
                        1024.70 1010.060 0.10 1024.70 1000.00 0.100
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_between_Unit1_Unit2_Unit3_Ceiling">
                    <gml:name>Floor_between_Unit1_Unit2_Unit3_Ceiling</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.70 1000.00 0 1024.90 1000.00 0 1024.90 1010.060 0 1024.70
                        1010.060 0 1024.70 1000.00 0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
```

```
                  <gml:Polygon gml:id="GML_between_Unit1_Unit2_Unit3_North">
                    <gml:name>Floor_between_Unit1_Unit2_Unit3_North</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.70 1010.060 0 1024.90 1010.060 0 1024.90 1010.060 0.10
                        1024.70 1010.060 0.10 1024.70 1010.060 0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_between_Unit1_Unit2_Unit3_South">
                    <gml:name>Floor_between_Unit1_Unit2_Unit3_South</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.70 1000.00 0.000 1024.900 1000.00 0.000 1024.900 1000.00
                        0.100 1024.70 1000.00 0.100  1024.70 1000.00 0.000
                      </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_between_Unit1_Unit2_Unit3_Side_Right">
                    <gml:name>Floor_between_Unit1_Unit2_Unit3_Side_Right</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.900 1000.000 0.000 1024.900 1010.060 0.000 1024.900 1010.060
                        0.100 1024.900 1000.000 0.100  1024.900 1000.000 0.000
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_between_Unit1_Unit2_Unit3_Side_Left">
                    <gml:name>Floor_between_Unit1_Unit2_Unit3_Side_Left</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.700 1000.000 0.000 1024.700 1010.060 0.000 1024.700 1010.060
                        0.100 1024.700 1000.000 0.100  1024.700 1000.000 0.000
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Floor>
    </bild:consistsOfStructuralComponent>
    <!-- ================ Wall_between_Unit1_Unit2_Unit3_1(lower)  ====================-->
    <bild:consistsOfStructuralComponent>
      <bild:Wall gml:id="DCDM_Wall_between_Unit1_Unit2_Unit3_lower">
        <bild:representedByMultiSurface>
          <gml:MultiSurface gml:id="DCDM_Wall_between_Unit1_Unit2_Unit3-lower">
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM_Wall_between_Unit1_Unit2-Unit3-lower">
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Interior_Unit1-2_lower">
                    <gml:name>Wall_between_Unit1_Unit2_Unit3_Interior_Unit1-2_lower</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1024.700 1000.000 0.10 1024.700 1010.060 0.10 1024.700 1010.060
                        3.0 1024.700 1000.000 3.0  1024.700 1000.000 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
```

```
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Interior_Unit3_lower">
                    <gml:name>Wall_between_Unit1_Unit2_Unit3_Interior_Unit3_lower</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1024.900 1000.000 0.10 1024.900 1010.060 0.10 1024.900 1010.060
                        3.0 1024.900 1000.000 3.0  1024.900 1000.000 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Floor_lower">
                    <gml:name>Wall_between_Unit1_Unit2_Unit3_Floor_lower</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.700 1000.000 0.10 1024.900 1000.00 0.10 1024.900 1010.060
                        0.10 1024.700 1010.060 0.10  1024.700 1000.000 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Ceiling_lower">
                    <gml:name>Wall_between_Unit1_Unit2_Unit3_Ceiling_lower</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.700 1000.000 3.0 1024.900 1000.00 3.0 1024.900 1010.060 3.0
                        1024.700 1010.060 3.0  1024.700 1000.000 3.0
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Side_North_lower">
                    <gml:name>Wall_between_Unit1_Unit2_Unit3_Side_North_lower</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.700 1010.060 0.10 1024.900 1010.060 0.10 1024.900 1010.060
                        3.0 1024.700 1010.060 3.0  1024.700 1010.060 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Side_South_lower">
                    <gml:name>Wall_between_Unit1_Unit2_Unit3_Side_South_lower</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1024.700 1000.00 0.10 1024.900 1000.00 0.10 1024.900 1000.00 3.0
                        1024.700 1000.00 3.0  1024.700 1000.00 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Wall>
    </bild:consistsOfStructuralComponent>
    <!-- =============== Wall_between_Unit1_Unit2_Unit3_1(upper)  ========================-->
    <bild:consistsOfStructuralComponent>
      <bild:Wall gml:id="DCDM_Wall_between_Unit1_Unit2_Unit3_upper">
        <bild:representedByMultiSurface>
```

```xml
<gml:MultiSurface gml:id="DCDM_Wall_between_Unit1_Unit2_Unit3-upper">
  <gml:surfaceMember>
    <gml:CompositeSurface gml:id="DCDM_Wall_between_Unit1_Unit2-Unit3-upper">
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Interior_Unit1-2_upper">
          <gml:name>Wall_between_Unit1_Unit2_Unit3_Interior_Unit1-2_upper</gml:name>
          <gml:exterior>
            <!-- -->
            <gml:LinearRing>
              <gml:posList>1020.640 1000.000 3.0 1020.640 1010.060 3.0 1020.640 1010.060 6.0
              1020.640 1000.000 6.0  1020.640 1000.000 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Exterior_Unit3_upper">
          <gml:name>Wall_between_Unit1_Unit2_Unit3_Exterior_Unit3_upper</gml:name>
          <gml:exterior>
            <!-- -->
            <gml:LinearRing>
              <gml:posList>1020.840 1000.000 3.0 1020.840 1010.060 3.0 1020.840 1010.060 6.0
              1020.840 1000.000 6.0  1020.840 1000.000 3.0</gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Floor_upper">
          <gml:name>Wall_between_Unit1_Unit2_Unit3_Floor_upper</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1020.640 1000.000 3.0 1020.840 1000.00 3.0 1020.840 1010.060 3.0
              1020.640 1010.060 3.0  1020.640 1000.000 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Ceiling_upper">
          <gml:name>Wall_between_Unit1_Unit2_Unit3_Ceiling_upper</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1020.640 1000.000 6.0 1020.840 1000.00 6.0 1020.840 1010.060 6.0
              1020.640 1010.060 6.0  1020.640 1000.000 6.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Side_North_upper">
          <gml:name>Wall_between_Unit1_Unit2_Unit3_Side_North_upper</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1020.640 1010.060 3.0 1020.840 1010.060 3.0 1020.840 1010.060 6.0
              1020.640 1010.060 6.0  1020.640 1010.060 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Side_South_upper">
          <gml:name>Wall_between_Unit1_Unit2_Unit3_Side_South_upper</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1020.640 1000.00 3.0 1020.840 1000.00 3.0 1020.840 1000.00 6.0
              1020.640 1000.00 6.0 1020.640 1000.00 3.0
              </gml:posList>
```

```xml
                        </gml:LinearRing>
                    </gml:exterior>
                </gml:Polygon>
            </gml:surfaceMember>
        </gml:CompositeSurface>
    </gml:surfaceMember>
    </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ====================== Floor_between_Unit1_Unit2_Unit3 (upper) ===================-->
<bild:consistsOfStructuralComponent>
  <bild:Floor gml:id="DCDM_Floor_between_Unit1_Unit2_Unit3_upper">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Floor_between_Unit1_Unit2_Unit3-upper">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM_Floor_between_Unit1_Unit2-Unit3-upper">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit2_Unit3_Interior_1">
                <gml:name>Floor_between_Unit1_Unit2_Unit3_Interior_1</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.840 1000.20 3.0 1024.90 1000.20 3.0 1024.90 1009.830 3.0
                    1020.840 1009.830 3.0 1020.840 1000.20 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit2_Unit3_Interior_3">
                <gml:name>Floor_between_Unit1_Unit2_Unit3_Interior_3</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.840 1000.20 3.20 1024.90 1000.20 3.20 1024.90 1009.830 3.20
                    1020.840 1009.830 3.20 1020.840 1000.20 3.20
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit2_Unit3_North">
                <gml:name>Floor_between_Unit1_Unit2_Unit3_North</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1009.830 3.0 1024.90 1009.830 3.0 1024.90 1009.830 3.20
                    1020.840 1009.830 3.20  1020.840 1009.830 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit2_Unit3_South">
                <gml:name>Floor_between_Unit1_Unit2_Unit3_South</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1020.840 1000.20 3.0 1024.90 1000.20 3.0 1024.90 1000.20 3.20
                    1020.840 1000.20 3.20  1020.840 1000.20 3.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit2_Unit3_Side_Right">
                <gml:name>Floor_between_Unit1_Unit2_Unit3_Side_Right</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
```

```
                        <gml:posList>1024.90 1000.20 3.0 1024.90 1009.830 3.0 1024.90 1009.830 3.20
                        1024.90 1000.20 3.20  1024.90 1000.20 3.20
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit2_Unit3_Side_Left">
                    <gml:name>Floor_between_Unit1_Unit2_Unit3_Side_Left</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1020.840 1000.20 3.0 1020.840 1009.830 3.0 1020.840 1009.830 3.20
                        1020.840 1000.20 3.20 1020.840 1000.20 3.20
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
              </gml:CompositeSurface>
            </gml:surfaceMember>
          </gml:MultiSurface>
        </bild:representedByMultiSurface>
      </bild:Floor>
    </bild:consistsOfStructuralComponent>
    <!-- ==================== Wall_Unit3 (Right side)  ==============================-->
    <bild:consistsOfStructuralComponent>
      <bild:Wall gml:id="DCDM_Wall_Unit3">
        <bild:representedByMultiSurface>
          <gml:MultiSurface gml:id="DCDM_Wall-Unit3">
            <gml:surfaceMember>
              <gml:CompositeSurface gml:id="DCDM-Wall-Unit3">
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_Unit3_Interior">
                    <gml:name>Wall_Unit3_Interior</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1035.770 1000.000 0.10 1035.770 1010.060 0.10 1035.770 1010.060
                        6.0 1035.770 1000.000 6.0  1035.770 1000.000 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_Unit3_Exterior">
                    <gml:name>Wall_Unit3_Exterior</gml:name>
                    <gml:exterior>
                      <!-- -->
                      <gml:LinearRing>
                        <gml:posList>1035.970 1000.000 0.10 1035.970 1010.060 0.10 1035.970 1010.060
                        6.0 1035.970 1000.000 6.0  1035.970 1000.000 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_Unit3_Floor">
                    <gml:name>Wall_Unit3_Floor</gml:name>
                    <gml:exterior>
                      <gml:LinearRing>
                        <gml:posList>1035.770 1000.000 0.10 1035.970 1000.000 0.10 1035.970 1010.060
                        0.10 1035.770 1010.060 0.10  1035.770 1000.000 0.10
                        </gml:posList>
                      </gml:LinearRing>
                    </gml:exterior>
                  </gml:Polygon>
                </gml:surfaceMember>
                <gml:surfaceMember>
                  <gml:Polygon gml:id="GML_Wall_Unit3_Ceiling">
```

```
                <gml:name>Wall_Unit3_Ceiling</gml:name>
                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1035.770 1000.000 6.0 1035.970 1000.000 6.0 1035.970 1010.060 6.0
                    1035.770 1010.060 6.0  1035.770 1000.000 6.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
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                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1035.970 1010.060 0.10 1035.770 1010.060 0.10 1035.770 1010.060
                    6.0 1035.970 1010.060 6.0  1035.970 1010.060 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
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                <gml:exterior>
                  <gml:LinearRing>
                    <gml:posList>1035.970 1000.00 0.10 1035.770 1000.00 0.10 1035.770 1000.00 6.0
                    1035.970 1000.00 6.0  1035.970 1000.00 0.10
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
          </gml:CompositeSurface>
        </gml:surfaceMember>
      </gml:MultiSurface>
    </bild:representedByMultiSurface>
  </bild:Wall>
</bild:consistsOfStructuralComponent>
<!-- ====================== Ceiling_Unit3  ========================================-->
<bild:consistsOfStructuralComponent>
  <bild:Ceiling gml:id="DCDM_Ceiling_Unit3">
    <bild:representedByMultiSurface>
      <gml:MultiSurface gml:id="DCDM_Ceiling-Unit3">
        <gml:surfaceMember>
          <gml:CompositeSurface gml:id="DCDM-Ceiling-Unit3">
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit3_Interior">
                <gml:name>Wall_Ceiling_Unit3_Interior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.840 1000.20 5.80 1035.770 1000.20 5.80 1035.770 1009.830 5.80
                    1020.840 1009.830 5.80 1020.840 1000.20 5.80
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
            </gml:surfaceMember>
            <gml:surfaceMember>
              <gml:Polygon gml:id="GML_Ceiling_Unit3_Exterior">
                <gml:name>Ceiling_Unit3_Exterior</gml:name>
                <gml:exterior>
                  <!-- -->
                  <gml:LinearRing>
                    <gml:posList>1020.840 1000.20 6.0 1035.770 1000.20 6.0 1035.770 1009.830 6.0
                    1020.840 1009.830 6.0 1020.840 1000.20 6.0
                    </gml:posList>
                  </gml:LinearRing>
                </gml:exterior>
              </gml:Polygon>
```

```xml
                    </gml:surfaceMember>
                    <gml:surfaceMember>
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                        <gml:name>Ceiling_Unit3_Side-Left</gml:name>
                        <gml:exterior>
                          <gml:LinearRing>
                            <gml:posList>1020.840 1000.20 5.80 1020.840 1009.830 5.80 1020.840 1009.830 6.0
                            1020.840 1000.20 6.0 1020.840 1000.20 5.80
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_Ceiling_Unit3_Side-Right">
                        <gml:name>Ceiling_Unit3_Side-Right</gml:name>
                        <gml:exterior>
                          <gml:LinearRing>
                            <gml:posList>1035.770 1000.20 5.80 1035.770 1009.830 5.80 1035.770 1009.830 6.0
                            1035.770 1000.20 6.0 1035.770 1000.20 5.80
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_Ceiling_Unit3_North">
                        <gml:name>Ceiling_Unit3_North</gml:name>
                        <gml:exterior>
                          <gml:LinearRing>
                            <gml:posList>1020.840 1009.830 5.80 1035.770 1009.830 5.80 1035.770 1009.830
                            6.0 1020.840 1009.830 6.0 1020.840 1009.830 5.80
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                    <gml:surfaceMember>
                      <gml:Polygon gml:id="GML_Ceiling_Unit3_South">
                        <gml:name>Ceiling_Unit3_South</gml:name>
                        <gml:exterior>
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                            1020.840 1000.20 6.0 1020.840 1000.20 5.80
                            </gml:posList>
                          </gml:LinearRing>
                        </gml:exterior>
                      </gml:Polygon>
                    </gml:surfaceMember>
                  </gml:CompositeSurface>
                </gml:surfaceMember>
              </gml:MultiSurface>
            </bild:representedByMultiSurface>
          </bild:Ceiling>
        </bild:consistsOfStructuralComponent>
        <!-- ==================== Space_Unit3 ======================================-->
        <bild:consistsOfSpace>
          <bild:Space gml:id="DCDM-Space-Unit-3">
            <bild:representedBySolid>
              <gml:Solid gml:id="DCDM_Space_Unit_3">
                <gml:exterior>
                  <gml:Shell>
                    <gml:surfaceMember>
                      <gml:CompositeSurface gml:id="DCDM_Space_Unit-3">
                        <!--  Floor_Unit_3  -->
                        <gml:surfaceMember>
                          <gml:Polygon gml:id="GML_Unit_3_Floor_Interior_legal">
                            <gml:name>Unit_3_Floor_Interior</gml:name>
                            <gml:exterior>
                              <gml:LinearRing>
                                <gml:posList>1024.900 1009.830 0.100 1035.770 1009.830 0.100  1035.770
                                1000.20 0.100 1024.900 1000.20 0.100 1024.900 1009.830 0.100
```

```
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <!-- Wall_South_Unit_3 -->
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Unit_3_Wall_South_Interior_legal">
            <gml:name>Unit_3_Wall_South_Interior</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1020.840 1000.20 3.20 1024.900 1000.20 3.200 1024.900 1000.20
                0.10 1035.770 1000.20 0.10 1035.770 1000.20 5.80 1020.840 1000.20 5.80
                1020.840 1000.20 3.20
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <!-- Wall_North_Unit_3 -->
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Unit_3_Wall_North_Interior_legal">
            <gml:name>Unit_3_Wall_North_Interior</gml:name>
            <gml:exterior>
              <gml:LinearRing>
                <gml:posList>1020.840 1009.830 3.20  1020.840 1009.830 5.80 1035.770
                1009.830 5.80 1035.770 1009.830 0.10  1024.900 1009.830 0.10 1024.900
                1009.830 3.200 1020.840 1009.830 3.20
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <!-- Wall_between_Unit1_Unit2_Unit3_lower -->
        <gml:surfaceMember>
          <gml:Polygon
          gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Interior_Unit3_lower_legal">
            <gml:name>Wall_between_Unit1_Unit2_Unit3_Interior_Unit3_lower</gml:name>
            <gml:exterior>
              <!-- -->
              <gml:LinearRing>
                <gml:posList>1024.900 1000.20 0.10 1024.900 1000.20 3.20  1024.900 1009.830
                3.20  1024.900 1009.830 0.10 1024.900 1000.20 0.10
                </gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <!-- Wall_between_Unit1_Unit2_Unit3_upper -->
        <gml:surfaceMember>
          <gml:Polygon
          gml:id="GML_Wall_between_Unit1_Unit2_Unit3_Exterior_Unit3_upper_legal">
            <gml:name>Wall_between_Unit1_Unit2_Unit3_Exterior_Unit3_upper</gml:name>
            <gml:exterior>
              <!-- -->
              <gml:LinearRing>
                <gml:posList>1020.840 1000.20 3.20 1020.840 1000.20 5.80  1020.840 1009.830
                5.80 1020.840 1009.830 3.20  1020.840 1000.20 3.20</gml:posList>
              </gml:LinearRing>
            </gml:exterior>
          </gml:Polygon>
        </gml:surfaceMember>
        <!-- Floor_between_Unit1_Unit2_Unit3 -->
        <gml:surfaceMember>
          <gml:Polygon gml:id="GML_Floor_between_Unit1_Unit2_Unit3_Interior_1_legal">
            <gml:name>Floor_between_Unit1_Unit2_Unit3_Interior_1</gml:name>
            <gml:exterior>
              <!-- -->
              <gml:LinearRing>
                <gml:posList>1020.840 1000.20 3.20  1020.840 1009.830 3.20  1024.90
                1009.830 3.20 1024.90 1000.20 3.20   1020.840 1000.20 3.20
                </gml:posList>
```

```
                                    </gml:LinearRing>
                                </gml:exterior>
                            </gml:Polygon>
                        </gml:surfaceMember>
                        <!--  Wall_Unit3  -->
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Wall_Unit3_Interior_legal">
                                <gml:name>Wall_Unit3_Interior</gml:name>
                                <gml:exterior>
                                    <!-- -->
                                    <gml:LinearRing>
                                        <gml:posList>1035.770 1000.20 0.10 1035.770 1009.830 0.10 1035.770
                                        1009.830 5.80 1035.770 1000.20 5.80  1035.770 1000.20 0.10
                                        </gml:posList>
                                    </gml:LinearRing>
                                </gml:exterior>
                            </gml:Polygon>
                        </gml:surfaceMember>
                        <!--  Ceiling_Unit3  -->
                        <gml:surfaceMember>
                            <gml:Polygon gml:id="GML_Ceiling_Unit3_Interior_legal">
                                <gml:name>Wall_Ceiling_Unit3_Interior</gml:name>
                                <gml:exterior>
                                    <!-- -->
                                    <gml:LinearRing>
                                        <gml:posList>1020.840 1000.20 5.80 1035.770 1000.20 5.80 1035.770 1009.830
                                        5.80 1020.840 1009.830 5.80 1020.840 1000.20 5.80
                                        </gml:posList>
                                    </gml:LinearRing>
                                </gml:exterior>
                            </gml:Polygon>
                        </gml:surfaceMember>
                    </gml:CompositeSurface>
                </gml:surfaceMember>
            </gml:Shell>
        </gml:exterior>
    </gml:Solid>
</bild:representedBySolid>
</bild:Space>
</bild:consistsOfSpace>
</bild:Unit>
</bild:consistsOfBuildingPart>
<!-- ======================= EndOfUnit3 ========================================-->
<!-- ============= CommonProperty_Pathway  =======================================-->
<bild:consistsOfBuildingPart>
    <bild:Pathway gml:id="DCDM_CommonProperty" lpoRef="CommonProperty">
        <!-- ================ Pathway's Legal Counterpart  ==============================-->
        <lpo>
            <lpo:LegalPropertyObject gml:id="CommonProperty" lpoClass="commonProperty" lpoUnit="single"
            lpoFormat="3DParcel" name="CommonProperty" lpoState="created" rrr="commonOwnership">
                <lpo:legalDocument>
                    <lpo:Title folio="725" volume="10564">
                        <lpo:locatedAs>
                            <lpo:LandDescription plan="SubdivisionPlan" planNo="422525J" lotNo="CP-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_CommonProperty_Pathway">
        </lpo:representedBySolid>
            </lpo:LegalPropertyObject>
        </lpo>
        <!-- =============== PhysicalPropertyObject  =================================-->
        <bild:representedBySolid>
            <gml:Solid gml:id="DCDM_CommonProperty_Pathway">
                <gml:exterior>
                    <gml:Shell>
```

```xml
<gml:surfaceMember>
  <gml:CompositeSurface gml:id="DCDM_CommonProperty-Pathway">
    <!-- Floor_CommonProperty -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Floor_CommonProperty_legal">
        <gml:name>Floor_CommonProperty_legal</gml:name>
        <gml:exterior>
          <gml:LinearRing>
            <gml:posList>1000.00 1000.000 0 1000.00 1010.060 0  1000.655 1010.060 0
            1000.630 1000.000 0 1000.00 1000.000 0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!-- Ceiling_CommonProperty -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Ceiling_CommonProperty_legal">
        <gml:name>Ceiling_CommonProperty_legal</gml:name>
        <gml:exterior>
          <gml:LinearRing>
            <gml:posList>1000.00 1000.000 3.0  1000.630 1000.000 3.0  1000.655 1010.060 3.0
            1000.00 1010.060 3.0    1000.00 1000.000 3.0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!-- Wall_CommonProperty_Right -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Wall_CommonProperty_Right_legal">
        <gml:name>Wall_CommonProperty_Right_legal</gml:name>
        <gml:exterior>
          <gml:LinearRing>
            <gml:posList>1000.630 1000.00 0 1000.655 1010.060 0  1000.655 1010.060 3.0
            1000.630 1000.00 3.0 1000.630 1000.00 0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!-- Wall_CommonProperty_Left -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Wall_CommonProperty_Left_legal">
        <gml:name>Wall_CommonProperty_Left_legal</gml:name>
        <gml:exterior>
          <gml:LinearRing>
            <gml:posList>1000.00 1000.00 0 1000.00 1000.00 3.0  1000.00 1010.060 3.0 1000.00
            1010.060 0  1000.00 1000.00 0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!-- Wall_CommonProperty_North -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Wall_CommonProperty_North_legal">
        <gml:name>Wall_CommonProperty_North_legal</gml:name>
        <gml:exterior>
          <gml:LinearRing>
            <gml:posList>1000.655 1010.060 0.0  1000.00 1010.060 0.0    1000.000 1010.060 3.0
            1000.655 1010.060 3.0  1000.655 1010.060 0.0
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:surfaceMember>
    <!-- Wall_CommonProperty_South -->
    <gml:surfaceMember>
      <gml:Polygon gml:id="GML_Wall_CommonProperty_South_legal">
        <gml:name>Wall_CommonProperty_South_legal</gml:name>
        <gml:exterior>
```

```xml
                    <gml:LinearRing>
                        <gml:posList>1000.00 1000.00 0.0  1000.630 1000.00 0.0   1000.630 1000.00 3.0
                        1000.00 1000.00 3.0  1000.00 1000.00 0.0
                        </gml:posList>
                    </gml:LinearRing>
                  </gml:exterior>
                </gml:Polygon>
              </gml:surfaceMember>
            </gml:CompositeSurface>
          </gml:surfaceMember>
        </gml:Shell>
      </gml:exterior>
    </gml:Solid>
  </bild:representedBySolid>
 </bild:Pathway>
</bild:consistsOfBuildingPart>
<!-- ===================End CommonProperty_Pathway ===============================-->
</bild:Building>
</physicalObjectMember>
<physicalObjectMember>
 <!-- ========================= Easement_Wall  ======================================-->
 <bild:Wall gml:id="DCDM_Easement_Wall" lpoRef="Easement">
  <!-- ================== PartyWall's Legal Counterpart  ================================-->
  <lpo>
   <lpo:LegalPropertyObject gml:id="Easement" lpoClass="easement" lpoUnit="single" lpoFormat="3DParcel"
   name="Easement" lpoState="created" rrr="easement">
    <lpo:legalDocument>
     <lpo:Title folio="725" volume="10564">
      <lpo:locatedAs>
       <lpo:LandDescription plan="SubdivisionPlan" planNo="422525J" lotNo="E-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_Easement_PartyWall">
    </lpo:representedBySolid>
   </lpo:LegalPropertyObject>
  </lpo>
  <!-- ====================== PhysicalPropertyObject  =================================-->
  <bild:representedBySolid>
   <gml:Solid gml:id="DCDM_Easement_PartyWall">
    <gml:exterior>
     <gml:Shell>
      <gml:surfaceMember>
       <gml:CompositeSurface gml:id="DCDM_Easement-PartyWall">
        <!--  Floor_Easement  -->
        <gml:surfaceMember>
         <gml:Polygon gml:id="GML_Floor_Easement_legal">
          <gml:name>Floor_Easement_legal</gml:name>
          <gml:exterior>
           <gml:LinearRing>
            <gml:posList>1000.655 1009.830 0.10 1000.655 1010.060 0.10  1013.720 1010.060 0.10
            1013.720 1009.830 0.10 1000.655 1009.830 0.10
            </gml:posList>
           </gml:LinearRing>
          </gml:exterior>
         </gml:Polygon>
        </gml:surfaceMember>
        <!--  Floor_Easement_Level2  -->
        <gml:surfaceMember>
         <gml:Polygon gml:id="GML_Floor_Easement_Level2_legal">
          <gml:name>Floor_Easement_Level2_legal</gml:name>
          <gml:exterior>
           <gml:LinearRing>
            <gml:posList>1000.00 1009.830 3.0 1000.00 1010.060 3.0  1000.655 1010.060 3.0
            1000.655 1009.830 3.0 1000.00 1009.830 3.0
            </gml:posList>
```

```xml
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <!-- Ceiling_Easement -->
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Ceiling_Easement_legal">
          <gml:name>Ceiling_Easement_legal</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.00 1009.830 6.0 1013.720 1009.830 6.0  1013.720 1010.060 6.0
              1000.00 1010.060 6.0 1000.00 1009.830 6.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <!-- Wall_Easement_Right -->
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Easement_Right_legal">
          <gml:name>Wall_Easement_Right_legal</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1013.720 1010.060 0.100 1013.720 1010.060 6.0 1013.720 1009.830 6.0
              1013.720 1009.830 0.10 1013.720 1010.060 0.100
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <!-- Wall_Easement_Left -->
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Easement_Left_legal">
          <gml:name>Wall_Easement_Left_legal</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.655 1010.060 0.100 1000.655 1009.830 0.10 1000.655 1009.830 3.0
              1000.655 1010.060 3.0   1000.655 1010.060 0.100
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <!-- Wall_Easement_Left_Level2 -->
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Easement_Left_Level2_legal">
          <gml:name>Wall_Easement_Left_Level2 _legal</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.00 1010.060 3.0 1000.00 1009.830 3.0 1000.00 1009.830 6.0 1000.00
              1010.060 6.0 1000.00 1010.060 3.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <!-- Wall_Easement_Left_Level2 -->
      <gml:surfaceMember>
        <gml:Polygon gml:id="GML_Wall_Easement_North_legal">
          <gml:name>Wall_Easement_North_legal</gml:name>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>1000.00 1010.060 6.0 1013.720 1010.060 6.0 1013.720 1010.060 0.10
              1000.655 1010.060 0.10 1000.655 1010.060 3.0 1000.00 1010.060 3.0  1000.00 1010.060
              6.0
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:Polygon>
      </gml:surfaceMember>
      <!-- Wall_Easement_Left_Level2 -->
      <gml:surfaceMember>
```

```xml
                        <gml:Polygon gml:id="GML_Wall_Easement_South_legal">
                          <gml:name>Wall_Easement_South_legal</gml:name>
                          <gml:exterior>
                            <gml:LinearRing>
                              <gml:posList>1000.00 1009.830 6.0 1000.00 1009.830 3.0 1000.655 1009.830 3.0 1000.655
                              1009.830 0.10 1013.720 1009.830 0.10 1013.720 1009.830 6.0  1000.00 1009.830 6.0
                              </gml:posList>
                            </gml:LinearRing>
                          </gml:exterior>
                        </gml:Polygon>
                      </gml:surfaceMember>
                    </gml:CompositeSurface>
                  </gml:surfaceMember>
                </gml:Shell>
              </gml:exterior>
            </gml:Solid>
          </bild:representedBySolid>
        </bild:Wall>
        <!-- =========================End Easement_Wall ==============================-->
      </physicalObjectMember>
    </UrbanModel>
  </physicalModel>
  <!-- =========================== Legal Model  ========================================-->
  <legalModel>
    <CadastralModel>
      <legalObjectMember>
        <!-- =================== ReferencePoint  ========================================-->
        <cpm:CadastralPoints gml:id="CPM_ID1">
          <cpm:referencePointMember>
            <!--  CadastralPoints Unit1  -->
            <cpm:CadastralPoint name="U1_L1_W1_A1" state="existing">
              <cpm:referencePoint>
                <gml:Point gml:id="U1_L1_W1-A1">
                  <gml:pos>1000.630 1000.000 0.0</gml:pos>
                </gml:Point>
              </cpm:referencePoint>
            </cpm:CadastralPoint>
            <cpm:CadastralPoint name="U1_L1_W2_B2" state="existing">
              <cpm:referencePoint>
                <gml:Point gml:id="U1_L1_W2-B2">
                  <gml:pos>1024.90 1000.000 0.0</gml:pos>
                </gml:Point>
              </cpm:referencePoint>
            </cpm:CadastralPoint>
            <cpm:CadastralPoint name="U1_L1_W2_C2" state="existing">
              <cpm:referencePoint>
                <gml:Point gml:id="U1_L1_W2-C2">
                  <gml:pos>1024.90 1005.030 0.0</gml:pos>
                </gml:Point>
              </cpm:referencePoint>
            </cpm:CadastralPoint>
            <cpm:CadastralPoint name="U1_L1_W3_D3" state="existing">
              <cpm:referencePoint>
                <gml:Point gml:id="U1_L1_W3-D3">
                  <gml:pos>1000.655 1005.030 0.0</gml:pos>
                </gml:Point>
              </cpm:referencePoint>
            </cpm:CadastralPoint>
            <!--  cpm:CadastralPoints Unit2  -->
            <cpm:CadastralPoint name="U2_L1_W1_A1" state="existing">
              <cpm:referencePoint>
                <gml:Point gml:id="U2_L1_W1-A1">
                  <gml:pos>1000.655 1005.030 0.0</gml:pos>
                </gml:Point>
              </cpm:referencePoint>
            </cpm:CadastralPoint>
            <cpm:CadastralPoint name="U2_L1_W2_B2" state="existing">
              <cpm:referencePoint>
                <gml:Point gml:id="U2_L1_W2-B2">
                  <gml:pos>1024.90 1005.030 0.0</gml:pos>
                </gml:Point>
              </cpm:referencePoint>
```

```xml
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U2_L1_W2_C2" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U2_L1_W2-C2">
                            <gml:pos>1024.90 1010.060 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U2_L1_W3_D3" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U2_L1_W3-D3">
                            <gml:pos>1000.655 1010.060 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <!--  cpm:CadastralPoints Unit3  -->
                <cpm:CadastralPoint name="U3_L1_W5_4" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U3_L1_W5-4">
                            <gml:pos>1024.90 1000.00 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U3_L1_W2_2" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U3_L1_W2-2">
                            <gml:pos>1035.970 1000.00 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U3_L1_W2_3" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U3_L1_W2-3">
                            <gml:pos>1035.970 1010.060 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U3_L1_W4_4" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U3_L1_W4-4">
                            <gml:pos>1024.90 1010.060 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U3_L2_W8_2" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U3_L2_W8-2">
                            <gml:pos>1020.840 1000.00 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U3_L2_W8_3" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U3_L2_W8-3">
                            <gml:pos>1020.840 1000.00 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
                <cpm:CadastralPoint name="U3_L1_W45_1_2" state="existing">
                    <cpm:referencePoint>
                        <gml:Point gml:id="U3_L1_W45_1-2">
                            <gml:pos>1024.90 1005.030 0.0</gml:pos>
                        </gml:Point>
                    </cpm:referencePoint>
                </cpm:CadastralPoint>
            </cpm:referencePointMember>
        </cpm:CadastralPoints>
    </legalObjectMember>
    <!-- ===================== End of ReferencePoint ==================================-->
    <!-- ========================= Surveying ======================================-->
    <legalObjectMember>
        <suvy:Survey gml:id="survey_ID1">
```

```xml
<suvy:surveyedBy>
  <suvy:surveyor name="Peter John" surveyorFirm="GlobeArray" regNumber="8145"/>
</suvy:surveyedBy>
<suvy:initialisation>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-1" setupID="IS-1">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U1_L1_W1_A1"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-2" setupID="IS-2">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U3_L2_W8_2"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-3" setupID="IS-3">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U3_L1_W45_1_2"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-4" setupID="IS-4">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U1_L1_W3_D3"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-5" setupID="IS-5">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U3_L2_W8_3"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-6" setupID="IS-6">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U2_L1_W3_D3"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-7" setupID="IS-7">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U1_L1_W2_B2"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-8" setupID="IS-8">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U1_L1_W2_C2"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-9" setupID="IS-9">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U2_L1_W2_C2"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-10" setupID="IS-10">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U3_L1_W2_3"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
  <suvy:SetupInstrument instrumentHeight="0" stationName="IS-11" setupID="IS-11">
    <suvy:referencePoint>
      <suvy:SetupPoint pntRef="U3_L1_W2_2"/>
    </suvy:referencePoint>
  </suvy:SetupInstrument>
</suvy:initialisation>
<suvy:observation>
  <suvy:ObservationGroup id="OG-1">
    <!--  Surveying LOT1-Level2  -->
    <suvy:reducedLineObservation>
      <suvy:RedHorizontalLineObservation name="RHLO-1" setupID="IS-1" targetSetupID="IS-2"
      azimuth="270.00" horizDistance="23.82" purpose="normal"/>
    </suvy:reducedLineObservation>
    <suvy:reducedLineObservation>
      <suvy:RedHorizontalLineObservation name="RHLO-2" setupID="IS-2" targetSetupID="IS-3"
      azimuth="0.00" horizDistance="5.26" purpose="normal"/>
    </suvy:reducedLineObservation>
    <suvy:reducedLineObservation>
```

```xml
    <suvy:RedHorizontalLineObservation name="RHLO-3" setupID="IS-3" targetSetupID="IS-4"
    azimuth="270.00" horizDistance="23.82" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-4" setupID="IS-4" targetSetupID="IS-1"
    azimuth="0.00" horizDistance="5.26" purpose="normal"/>
  </suvy:reducedLineObservation>
  <!-- Surveying LOT2-Level2 -->
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-5" setupID="IS-3" targetSetupID="IS-4"
    azimuth="90.00" horizDistance="23.82" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-6" setupID="IS-4" targetSetupID="IS-6"
    azimuth="0.00" horizDistance="5.26" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-7" setupID="IS-6" targetSetupID="IS-5"
    azimuth="90.00" horizDistance="23.82" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-8" setupID="IS-5" targetSetupID="IS-3"
    azimuth="0.00" horizDistance="5.26" purpose="normal"/>
  </suvy:reducedLineObservation>
  <!-- Surveying LOT3(Over Lot1)-Level2 -->
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-9" setupID="IS-2" targetSetupID="IS-7"
    azimuth="90.00" horizDistance="4.16" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-10" setupID="IS-7" targetSetupID="IS-8"
    azimuth="0.00" horizDistance="5.26" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-11" setupID="IS-8" targetSetupID="IS-3"
    azimuth="90.00" horizDistance="4.16" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-12" setupID="IS-3" targetSetupID="IS-2"
    azimuth="0.00" horizDistance="5.26" purpose="normal"/>
  </suvy:reducedLineObservation>
  <!-- Surveying LOT3(Over Lot2)-Level2 -->
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-13" setupID="IS-3" targetSetupID="IS-8"
    azimuth="90.00" horizDistance="4.16" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-14" setupID="IS-8" targetSetupID="IS-9"
    azimuth="0.00" horizDistance="5.26" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-15" setupID="IS-9" targetSetupID="IS-5"
    azimuth="90.00" horizDistance="4.16" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-16" setupID="IS-5" targetSetupID="IS-3"
    azimuth="0.00" horizDistance="5.26" purpose="normal"/>
  </suvy:reducedLineObservation>
  <!-- Surveying LOT3-Level1 -->
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-17" setupID="IS-7" targetSetupID="IS-11"
    azimuth="90.00" horizDistance="11.17" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-18" setupID="IS-11" targetSetupID="IS-10"
    azimuth="0.00" horizDistance="10.12" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
    <suvy:RedHorizontalLineObservation name="RHLO-19" setupID="IS-10" targetSetupID="IS-9"
    azimuth="90.00" horizDistance="11.17" purpose="normal"/>
  </suvy:reducedLineObservation>
  <suvy:reducedLineObservation>
```

```xml
                <suvy:RedHorizontalLineObservation name="RHLO-20" setupID="IS-9" targetSetupID="IS-7"
                azimuth="0.00" horizDistance="10.12" purpose="normal"/>
              </suvy:reducedLineObservation>
            </suvy:ObservationGroup>
          </suvy:observation>
        </suvy:Survey>
      </legalObjectMember>
      <!-- ========================= End of Surveying  ====================================-->
    </CadastralModel>
  </legalModel>
  <!-- ========================= End of Legal Model  ========================================-->

</UrabnCadastralModel>
```