A standards-based portal for integrated Land Administration information

A case study of the Netherlands

by
Marjolein van Aalst

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Delft University of Technology

Thesis committee:	Prof. dr. ir. P.J.M. van Oosterom,	TU Delft, supervisor
	Dr. H.D. Ploeger,	TU Delft, co-supervisor
	Prof. em. dr. ir. C.H.J. Lemmen,	University Twente, co-reader

External committee:	Dr. ir. L. Rowland,	Kadaster, supervisor
	Dr. ir. E.J.A. Folmer,	Kadaster, supervisor

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Abstract

Land administration is the organized and systematic process of establishing and maintaining information about land. The efficient practice of land administration is anticipated to organize land registers for the provision of cross-sector and cross-border land administration services. Such a system should provide fundamental information regarding land administration without requiring access to land registers or geoportals. Due to disaggregated land administration systems in the Netherlands, land administration information related to the Dutch territory must be accessed through various geoportals. These geoportals include PDOK, Ruimtelijkeplannen, Wozwaardeloket, Bagviewer, and Kaartenvannederland. These geoportals utilize different approaches to information delivery, processing and retrieval. The basic assumption for the functionality of land administration is the interoperability of data from different registers and geoportals containing land administration information. Therefore, there appears to be a need for an integrated land administration information system. The Land Administration Domain Model (LADM) as a conceptual model is a way to integrate land administration information into the organized environment of a Spatial Data Infrastructure (SDI) for efficient data organization and accessibility. The second edition of LADM consists of five parts about the generic conceptual model, land registration, marine georegulation, valuation information and spatial plan information. This study examines the benefits and drawbacks of the implementation of the LADM Edition II for data dissemination in the Netherlands with a linked data portal.

An analysis has been conducted on the current state of LADM Edition II. Two use cases were identified and modelled to assess the implementation of LADM. Country profiles of the Netherlands were developed to adapt the model to country-specific needs. Linked data, a technique based on standardized web technologies, can enhance the capabilities of an SDI. To enable the implementation of the model with linked data, the country profiles were converted into an OWL ontology model, and datasets based on the Dutch registers were created in accordance with the ontology. Finally, a data story was developed using SPARQL queries to query and present the data for the use cases. A data story is a narrative that makes data comprehensible to a wider audience.

The assessment shows that the implementation of LADM Edition II for data dissemination in the Netherlands with a linked data portal has the potential to offer benefits in terms of time efficiency, resource efficiency and usability. This is the result of linking multiple registers from different domains of land administration, which enables the consultation of a single geoportal, the data story. However, this requires significant investment. The country profile has to be validated, datasets have to be created according to the ontology by matching the attributes in the Dutch registers with the attributes in LADM, and SPARQL queries have to be written to retrieve the data. These last two steps require a thorough understanding of the Dutch land administration systems and the ontology, and can be a time-consuming task. It remains to be seen whether the benefits of LADM in the Dutch context are worth the investment required for implementation.

Key words: land administration, the Netherlands, LADM Edition II, use cases, country profile, linked data portal

Contents

Acronyms

BAG	Basisregistratie Adressen en Gebouwen
BGT	Basisregistratie Grootschalige Topografie
BRI	Basisregistratie Inkomen
BRK	Basisregistratie Kadaster
BRK-PB	Basisregistratie Kadaster Publiekrechtelijke Beperkingen
BRO	Basisregistratie Ondergrond
BRP	Basisregistratie Personen
BRT	Basisregistratie Topografie
BRV	Basisregistratie Voertuigen
BSN	Burgerservicenummer
BZK	Ministerie van Binnenlandse Zaken en Koninkrijksrelaties
DSR	Design Science Research
ETL	Extraction, Transformation, and Load
GIS	Geographic Information System
GML	Geography Markup Language
HR	Basisregistratie Handelsregister
HTTP	Hypertext Transfer Protocol
IMKL	Informatiemodel Kabels en Leidingen
ISO	International Organization for Standardization
KG	Knowledge Graph
KKG	Kadaster Knowledge Graph
KLIC	Kabels en Leidingen Informatie Centrum
KML	Keyhole Markup Language
KOS	Knowledge Organization System
KvK	Kamer van Koophandel
LADM	Land Administration Domain Model
LAS	Land Administration System
Loki	Location-Based Land Registry Information

LV BAG	Landelijke Voorziening BAG
OWL	Web Ontology Language
PB	Publiekrechtelijke Beperkingen
PDF	Portable Document Format
PDOK	Publieke Dienstverlening Op de Kaart
RDF	Resource Description Framework
RRR	Right, Restriction, Responsibility
RVO	Rijksdienst voor Ondernemend Nederland
SDI	Spatial Data Infrastructure
SVIR	Structuurvisie Infrastructuur en Ruimte
SWG	Standards Working Group
UML	Unified Modelling Language
UN-GGIM	United Nations Committee of Experts on Global Geospatial Information Management
URIs	Uniform Resource Identifiers
VROM	Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer
W3C	World Wide Web Consortium
WFS	Web Feature Service
WKPB	Wet Kenbaarheid Publiekrechtelijk Beperkingen Onroerende Zaken
WMS	Web Mapping Service
WOZ	Basisregistratie Waarde Ontroerende Zaken
WRO	Wet Ruimtelijke Ordening

Glossary

Disclaimer: This glossary has been compiled for the context of the Netherlands.

Base register (Basisregistratie) = The Dutch government has established base registers as the mandatory sources for data registration for all governmental institutions when executing their public duties [Digital Government, 2023].

Cadastre = Base land register (BRK) of the Netherlands.

Geoportal = A web environment which acts as an access point to the shared land administration data [He et al., 2011].

Kadaster = The Kadaster is an independent administrative body under the Ministry of the Internal Affairs and Kingdom Relations (BZK). Its main duties are maintaining public registers, maintaining and updating the base land register, maintaining a network of coordinate points, maintaining and updating a registration for ships and aircraft, and the uniform, consistent and nationwide collection, geometric recording, management and cartographic representation of geographical data as well as maintaining and updating the basic topography register [Overheid, 2024a].

Land = The spatial extent to be covered by rights, restrictions and responsibilities, encompassing the wet and dry parts of the earth surface, including all space above and below the surface [ISO, 2023].

Land Administration = The organized and systematic process of establishing, maintaining and disseminating information about land, including land tenure (RRR), land use, land use planning, land valuation, land development and land registration. This definition is based on the definition of land administration provided by the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM).

Land Administration data = Data that is established, maintained and disseminated during the process of land administration.

Land Administration System = Comprises the legal, institutional, and technical framework that supports land administration.

Land Administration Domain Model = A conceptual model based on a practical approach. It describes the data contents and relationships of land administration and can be extended and adapted to specific situations.

Land register = Public register.

Rights, Responsibilities and Restrictions (RRR) = A 'right' is a formal or informal entitlement to own, to do something, or to refrain someone from doing something. In the context of land administration this right is regarding land ownership (e.g. ownership right, apartment right, tenancy right or possession). A right can be an (informal) use right, and rights may be overlapping, or may be in disagreement. A 'responsibility' is a formal or informal obligation to so something. This means in the context of land administration obligations or duties associated with land ownership (e.g. adherence to certain land use practices or payment of property taxes). A 'restriction' is a formal or informal limitation or condition imposed. In the context of land administration, this refers to the use or transfer of land (e.g. zoning regulations) [Lemmen et al., 2010].

Spatial data = The definition by the International Organization for Standardization (ISO) is adopted, stating spatial data as data with explicit or implicit reference to a location relative to the Earth's surface (ISO 19115-1:2014).

Spatial Data Infrastructure = A framework consisting of the institutional arrangements, policies, standards, and technologies that enables the collection, maintenance, and distribution of spatial data to meet user needs [European Commission, nd].

User = Anyone who interacts with land administration information, including professionals and non-professionals.

1. Introduction

This chapter introduces the topic of this thesis, and describes the problem statement in Section 1.1. The scientific relevance of this thesis is discussed in Section 1.2. Following, the main research questions as well as the sub-research questions are presented in Section 1.3. Section 1.4 discusses the scope of this thesis, followed by Section 1.5 which elaborates the Design Science Research. Lastly, the structure of this thesis is described in Section 1.6.

Land administration is the organized and systematic process of establishing and maintaining information about land, including land tenure, land use, land use planning, land valuation and land registration, to support effective land management and governance. This definition is based on the definition of land administration provided by the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). Land Administration Systems (LASs) are structured to support the four main functions of land administration: land tenure, land value, land use, and land development [Williamson, 2001]. Each country must establish an efficient, effective, and secure LAS to support sustainable development and good land management practices [Dale and McLaughlin, 1999].

Responsibilities and tasks related to land administration may be distributed among different organizations and authorities. If so, these organizations and authorities are likely to deal with different administrative domains and have different operational aspects, such as how information is provided, processed and retrieved. The efficient practice of land administration is anticipated to organize land registers for the provision of cross-sector and cross-border land administration services. Such a system should provide fundamental information regarding land administration without requiring access to land registers or geoportals [Çağdaş and Stubkjær, 2014]. The Land Administration Domain Model (LADM) offers a conceptual model which supports the expression of legal, geometric and semantic features of properties for functional land management, and facilitates the effective implementation of land administration [Van Oosterom and Lemmen, 2015]. The model, which consists of five parts about the generic conceptual model, land registration, marine georegulation, valuation information and spatial plan information is presented in LADM Edition II. Providing a shared ontology, thus defining a terminology, is crucial for effective communication among users and for facilitating the exchange and management of data quality. Individuals who interact with land administration information are referred to as users. This group can include both professionals and non-professionals. LADM includes a standardized terminology, serving as the foundation for regional and national profiles, and enabling the combination of land administration data from different sources [ISO, 2012]. LADM provides a flexible conceptual schema, that can facilitate the exchange of data to and from different land registers or geoportals [Van Oosterom and Lemmen, 2015].

1.1. Problem statement

Land is defined as the spatial extent to be covered by rights, restrictions and responsibilities, encompassing the wet and dry parts of the earth surface, including all space above and below the surface [ISO, 2023]. Land that is within the borders of the Netherlands is Dutch territory. Currently, information related to the Dutch territory must be accessed through various geoportals due to the country's disaggregated LASs. These geoportals include PDOK [Kadaster, ndc], Ruimtelijkeplannen [Rijksoverheid et al., nd], Wozwaardeloket [Rijksoverheid, nd], Bagviewer [Kadaster, nda], and Kaartenvannederland [Kadaster and BZK, nd]. The home page of the geoportals is displayed in Figure 1.1. These geoportals acquire their data from distributed sources, including land registers maintained by different organizations such as Kadaster, Waarderingskamer (Council for Real Estate Assessment) and municipalities. These geoportals utilize different approaches to information delivery, processing, and retrieval. The basic assumption for the functionality of land administration is the interoperability of data from different registers and geoportals containing land administration information [Mika, 2017]. So there seems to be an ambition for an integrated land information system, such a system can be structured by a data model that clearly identifies the attributes of these registers and the relationships between them [Çağdaş and Stubkjær, 2014].

(a) PDOK [Kadaster, ndc]

(b) Ruimtelijkeplannen [Rijksoverheid et al., nd]

(c) Wozwaardeloket [Rijksoverheid, nd]

(d) Bagviewer [Kadaster, nda]

(e) Kaartenvannederland [Kadaster and BZK, nd]

Figure 1.1: Geoportals in the Netherlands

A Spatial Data Infrastructure (SDI) is a framework consisting of the institutions, policies, standards, and technologies that collect, maintain, and distribute spatial data to meet user needs [European Commission, nd]. LADM as a conceptual model is a way to integrate land administration data in the organized environment of an SDI for efficient data organization and accessibility. The LADM establishes a common ontology enabling users to communicate effectively by use and exchange of data. Secondly, it supports the development of a land administration system, particularly involving multiple organizations. Lastly, LADM supports the creation of application software with the data model at its core, and allows for the exchange of land administration data. This capability must exist within an SDI to allow for exchange between land registers. The ultimate objective is to aid in data quality management. With the above-mentioned objectives, LADM holds the promise of being a potential solution when responsibilities and tasks related to land administration are distributed among different branches of government or organizations [Lemmen et al., 2015].

Linked data, a technique based on standardized web technologies, can implement and enhance the capabilities of an SDI. National mapping agencies are exploring the potential of publishing official government data utilizing linked data [Ronzhin et al., 2019]. By adhering to linked data principles, land administration data can seamlessly link together, facilitating access and navigation. In summary, linked data principles are highly relevant to the development of application software with LADM at its core to show the value of LADM. These principles augment the capabilities of the data model by making data more interconnected, improving interoperability, and enabling efficient data exchange, all of which are important in land administration where multiple organizations and information systems need to work together.

The Dutch Cadastre, Land Registry and Mapping Agency, in short: Kadaster, registers land administration data on behalf of the Dutch government, including ownership and rights. Due to this central role, they manage crucial land registers and geoportals of the Netherlands. It is worth noting that despite these important responsibilities, the Kadaster and other organizations that manage geoportals do not use the LADM standard to create an integrated national system [Hagemans et al., 2022]. In theory, the application of LADM appears effective, but the question is if this application actually provides a solution in practice? This study examines the application, implementation and benefits and drawbacks of LADM in the Netherlands, utilizing an SDI approach and linked data. The study adopts the ISO 19152 standard LADM Edition II. A prototype will be created using linked data technologies to implement the country profile conceptual model of the Netherlands. Then, use cases will be compared and evaluated to analyze the benefits and drawbacks of the LADM implementation in the Netherlands.

1.2. Scientific relevance

Countries with disaggregated LASs fail to take advantage of the opportunities that may exist in their separate LASs to address national needs [Bennett et al., 2012]. Misunderstandings between users can be the result of the lack of shared concepts and terminology. It seems to be essential to establish concepts and terminology based on a standardized national model, such as the LADM [Zulkifli et al., 2015a]. The term 'national' is extensively used in current influential literature on land administration to convey the requirement for an unified national approach. The United Nations Integrated Geospatial Information Framework (UN-IGIF) also emphasizes the need for cross-sectoral and multidisciplinary collaboration on data that support people's activities and their interaction with the built and natural environment [Krizanovic et al., 2023]. Considering the broader international context, the implementation of an international standard at the national level would represent a significant advance toward achieving interoperability between countries. As LADM Edition II is still under development, the findings of this thesis can provide feedback and recommend possible changes to further optimize the revised version before it is officially adopted. This study will assess and evaluate the implementation of LADM in the Netherlands utilizing use cases and offer recommendations for future developmental work.

1.3. Research questions

The main research question of this thesis study is:

What are the benefits and drawbacks of a linked data portal based on the Land Administration Domain Model (LADM) Edition II concepts?

The aim of this thesis is to research the potential of applying and implementing LADM in the context of the Netherlands. In order to answer the main research question, the following sub-questions are relevant:

1. What are relevant use cases to demonstrate the potential added value of applying the LADM Edition II within the context of the Netherlands?
2. What is the state of the art on the LADM Edition II?
3. How can the country profile of the Netherlands be conceptually modelled as it pertains to parts 1, 2, 4 and 5 of the LADM Edition II, and what are the intended and unintended consequences in this modelling?
4. How can linked data be employed to implement the conceptual model of the country profile of the Netherlands based on LADM Edition II, and what are the intended and unintended consequences in this implementation?
5. What are the intended and unintended consequences following the LADM-based approach in the use cases as demonstrated through the developed prototype?

1.4. Scope

This research will exclusively addresses land administration pertaining to the Dutch territory, with further spatial constraints limiting consideration to only 2-dimensional data. The study utilizes the base register of addresses and buildings (BAG), the base land register (BRK), the public law restrictions (PB), and the WOZ-value, as well as the geoportals Wozwaardeloket, and Ruimtelijkeplannen as the foundation for valuation information and spatial plan information in the Netherlands.

The scope of this study does not include 3-dimensional land administration visualizations related to the context of the Netherlands, nor will it include land administration data related to foreign territory. In addition, datasets concerning underground infrastructure networks (IMKL) (KLIC), underground geology and soil (BRO) and maritime areas (Part 3 of LADM Edition II) are excluded. Furthermore, the focus of this research will be on data dissemination, considering the provision of the requested information to the user. It does not address the process of data registration, which serves to add, modify or update information in a register. Finally, this research will not address privacy and authorization issues that may arise. Due to the complexity and time constraints of this thesis, it was decided to leave these elements out of scope.

1.5. Design Science Research

Design Science Research (DSR) is a problem-solving thinking approach that seeks to enhance people's knowledge through the development of innovative artefacts [Brocke et al., 2020]. This thesis develops and presents a prototype, in the form of a data story, of an integrated portal based on the multi-part Land Administration Domain Model (LADM) Edition II using linked data implementation. The development of the prototype portal starts with the identification of use cases and the modelling of their processes, as outlined in Chapter 4. Following this, the country profile of the Netherlands is developed and described in Chapter 5. This country profile is implemented using linked data technologies and data stories are created, which is described in Chapter 6.

1.6. Thesis outline

This thesis begins by reviewing literature and context on the Land Administration Domain Model and the state of the art of LADM Edition II, land administration in the Netherlands, the development of a country profile, linked data and the Kadaster Knowledge Graph in Chapter 2. Chapter 3 elaborates on the design of the prototype, including the required datasets and tools. The process models of the use cases are discussed in Chapter 4, the development of the country profile of the Netherlands is discussed in Chapter 5, and the implementation of this country profile with linked data is elaborated on in Chapter 6. The assessment and evaluation of the prototype is discussed in Chapter 7. Chapter 8 includes the discussion and limitations of this study, and Chapter 9 concludes this thesis by answering the research questions, and stating recommendations for future research.

This chapter introduced the topic of this thesis research, discussed the problem to be solved, and the scientific relevance of why this problem is relevant to be solved. This chapter also identified the main research question and five sub-research questions. Lastly, this chapter also introduced the scope of this thesis and the Design Science Research approach. The following chapter will discuss the literature and contextual review of the thesis topic.

2. Literature and contextual review

This chapter discusses literature and context to the topic of this thesis. First, the Land Administration Domain Model and its multi-parts is explained in Section 2.1, after which land administration in the Netherlands is described in Section 2.2. Third, the development of a country profile is elaborated on in Section 2.3. Finally, the principles of linked data are explained in Section 2.4, and the Kadaster Knowledge Graph is described in Section 2.5.

2.1. Land Administration Domain Model

To understand the Land Administration Domain Model (LADM) one must understand the Unified Modelling Language (UML) as LADM is modelled in UML. The UML defines various types of relationships between classes. Table 2.1 describes the most important relationships [Rumbaugh et al., 1998].

Relationship	*Function*	*Notation*	*Designation*
An association	Shows any type of relationship or connection between classes.	A line	Has
A direct association	Shows a strong relationship between classes, the classes must communicate.	A line with open arrow	Has exclusively
Inheritance	Shows that a child class inherits its functionality from the parent class.	A line with closed arrow	Is
An aggregation	Shows that two classes are associated, but not as close as in direct association. The child class can exist independent of the parent element.	An open diamond	Can have
An exclusive aggregation	Shows that two classes are associated, the child cannot exist independent of the parent element.	A closed diamond	Must have
Realization	Indicates that a class implements an interface.	Dotted line	Implements

Table 2.1: UML relationships

The Land Administration Domain Model (ISO 19152) is a conceptual model based on a practical approach. It describes the information contents of land administration and can be extended and adapted to specific situations [Lemmen et al.,][Çağdaş et al., 2016]. The main packages of the first edition of LADM are:

The Party package Parties are persons, groups of persons or legal persons, that make an identifiable single (legal) entity, representing legal and natural people.

Administrative package Rights, restrictions and responsibilities (RRR), dealing with the rights, restrictions and responsibilities associated with a basic administrative unit of land administration.

The Spatial Unit package Based on a point or line representing a single area or multiple areas of space, defining spatial units and their geometric and topological representation.

Figure 2.1 shows a general overview of LADM [Lemmen et al., 2015].

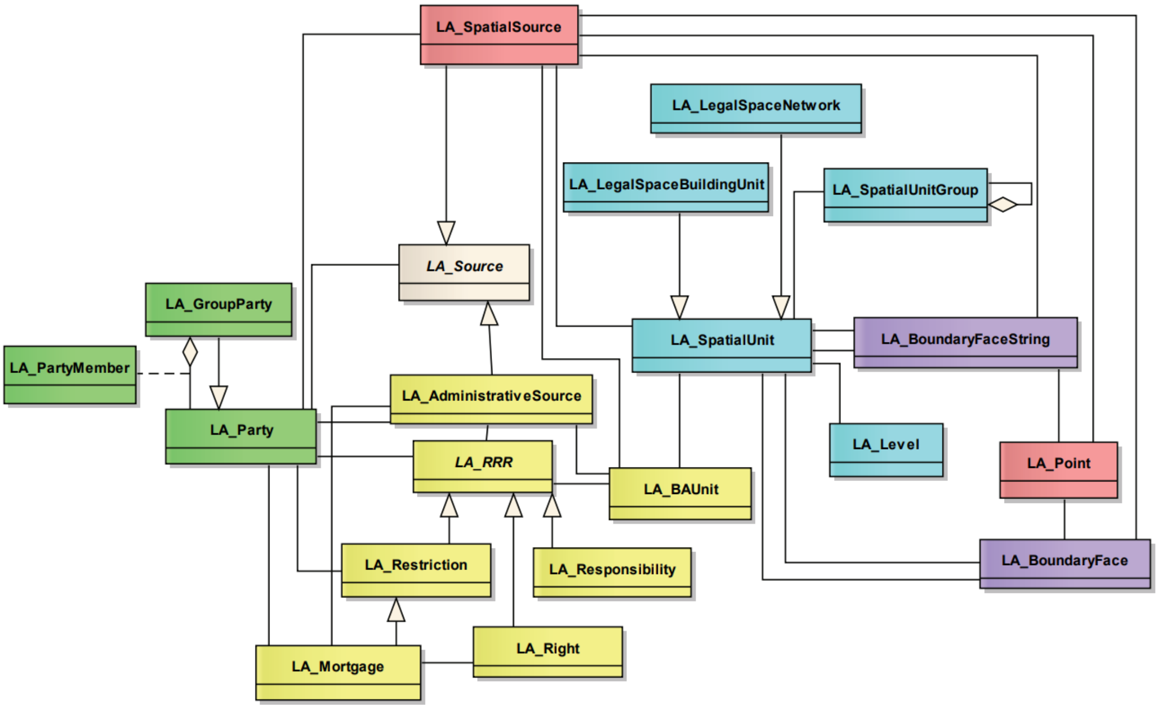


Figure 2.1: Overview of the Land Administration Domain Model [ISO, 2012]

The functionality included in the first edition of LADM is also included in the second edition of LADM [Van Oosterom et al., 2022]. The revised version of LADM is published as a multipart, containing five parts, each part having a prefix that identifies the UML package in which a class is defined, as is stated in Table 2.2. Each part constitutes separate standards, and each part will go through the full standardization process. Although the revised version is still under development, it is stable enough to be used as the basis for this thesis study. The five parts of LADM Edition II are briefly explained below.

Part	**Prefix**
Part 1 - Generic conceptual model	LA
Part 2 - Land registration	LA
Part 3 - Marine georegulation	MG
Part 4 - Valuation model	VM
Part 5 - Spatial plan information	SP

Table 2.2: Prefixes of LADM classes

In line with the scope, the current state of parts 1, 2, 4 and 5 of the second edition of the LADM is documented.

2.1.1. Part 1 - Generic Conceptual Model

The information in this subsection is based upon information from the ISO overview document for Part 1 - Generic conceptual model [ISO, 2023]. This part has been voted for by ISO member bodies and is approved. The first goal of this part is to enable involved parties, both within one country and between different countries, to communicate based on the shared vocabulary implied by the model. The second goal is to provide an extensible basis for the development of effective land administration systems, and for the creation of standardized information services at a national or international context where semantics have to be shared between organizations in order to enable necessary translation. Note that to achieve this second goal, the 4 other parts of LADM are also required.

Terms and definitions For the purpose of this documentation, the following terms and definitions apply.

Term	*Definition*	*Note to entry*
Basic administrative unit (BAUnit)	An administrative entity which can be subject to registration (by law) or recordations, and to which one or more unique and homogeneous rights, responsibilities or restrictions are attached as contained in a land administration system.	A BAUnit should be assigned a unique identifier when registered or recorded.
Group party	Any number of parties, together forming a distinct entity, which each party registered.	A group party may be a party member of another group party.
Party	A person or organization that plays a role in any land administration process.	A basic administrative unit may be a party.
Required relationship	An explicit association between either spatial units or between basic administrative units.	
Source	A document providing legal, spatial and/or administrative facts on which the land administration object is based.	
Spatial unit	Feature type related to land administration with associated spatial and thematic attributes.	Spatial units are structured in a way to support the creation and management of basic administrative units.

Part 1 provides a general overview of the model and serves as an overarching standard that supports Parts 2 to 5 and is backward compatible with the first edition of LADM. It defines the basic components and relationships common to all land administration objects, and provides an overview of all parts, including those over water and land, and elements above and below the earth's surface [Van Oosterom et al., 2022]. This part also provides a terminology for land administration, a basis for national and regional profiles and enables land administration data from different sources to be combined [Body et al., 2022].

The conceptual schema is described in the UML, following the guidance of ISO 19103. Names of UML classes, with the exception of basic data type classes, include a two-letter prefix that identifies the document and the UML package in which the class is defined. The prefixes are earlier shown in Table 2.2. LADM is organized in a set of packages and sub-packages, a sub-package is a group of classes with a certain degree of cohesion. Figure 2.2 shows the packages of core LADM, and will be described in more detail later in this section.

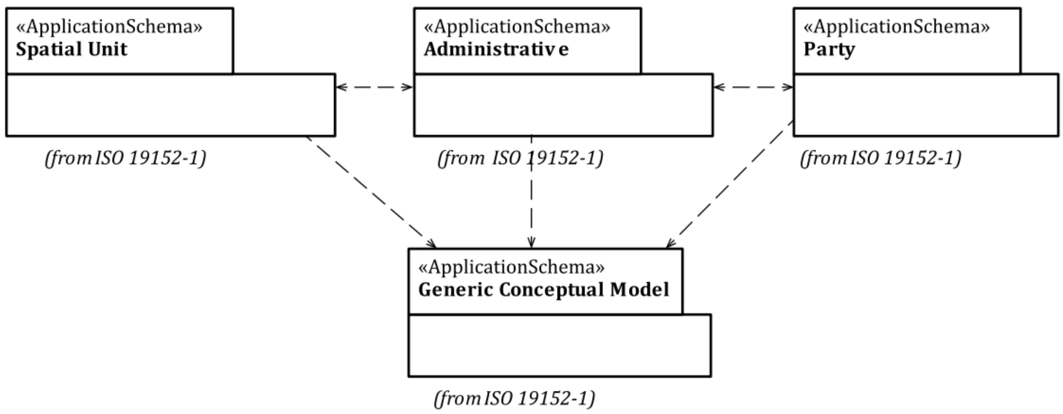


Figure 2.2: (Sub)Packages of core LADM [Kara et al., 2024]

Core LADM is based on four basic classes (see Figure 2.3), all inheriting from VersionedObject, and associated to LA_Source:

1. Class LA_Party. Instances of this class are parties.
2. Class LA_RRR. Instances of subclasses of LA_RRR are rights, restrictions or responsibilities.
3. Class LA_BAUnit. Instances of this class are basic administrative units.
4. Class LA_SpatialUnit. Instances of this class are spatial units.
5. Class VersionedObject. This class is an abstract class and subclasses of VersionedObject are all LADM classes, except LA_Source and its subclasses.
6. Class LA_Source. Instances of this class are sources, i.e. administrative and spatial.

The main packages of Part 1 - Generic conceptual model are described below.

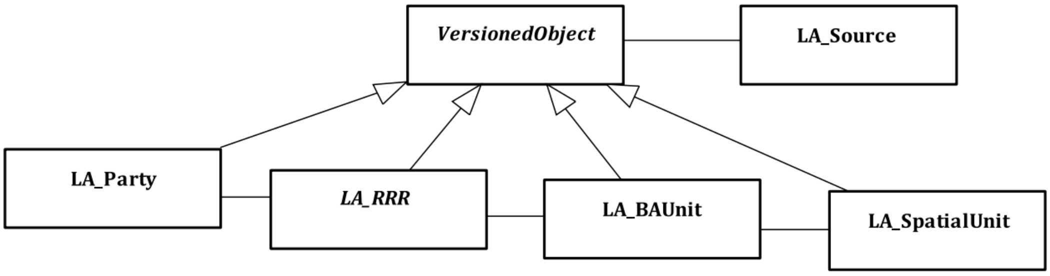


Figure 2.3: Basic classes of core LADM [Kara et al., 2024]

Party package The main class of the Party package is the basic class LA_Party, with party as an instance. LA_GroupParty is the specialization of LA_Party, with group party as an instance. Between LA_Party and LA_GroupParty there is an optional association class, LA_PartyMember, with party member as an instance. Any party that is a member of a LA_GroupParty can be registered as a party member of the LA_PartyMember class.

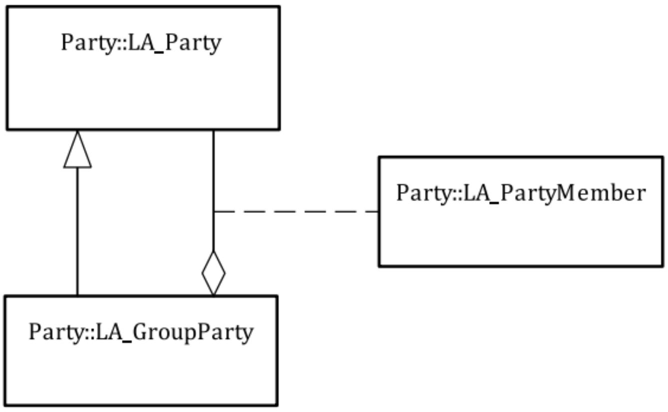


Figure 2.4: Classes of the Party package [Kara et al., 2024]

Administrative package The main classes of the Administrative package are the basic classes LA_RRR and LA_BAUnit. LA_RRR is an abstract class with three specializations classes: LA_Right, with rights as instances, LA_Restriction, with restrictions as instances, and LA_Responsibility, with responsibilities as instances. LA_BAUnit is a core class of the model and defines the elements upon which rights, restrictions and responsibilities apply. Instances of LA_BAUnit are basic administrative units.

All rights, restrictions and responsibilities are based on an administrative source, as instances from class LA_AdministrativeSource. LA_RequiredRelationshipBAUnit allows for the creation of instances of relationships between BAUnits. These relationships can be legal, temporal or of a spatial nature. The class LA_RequiredRelationshipRRR allows for creating instances of relationships between RRR.

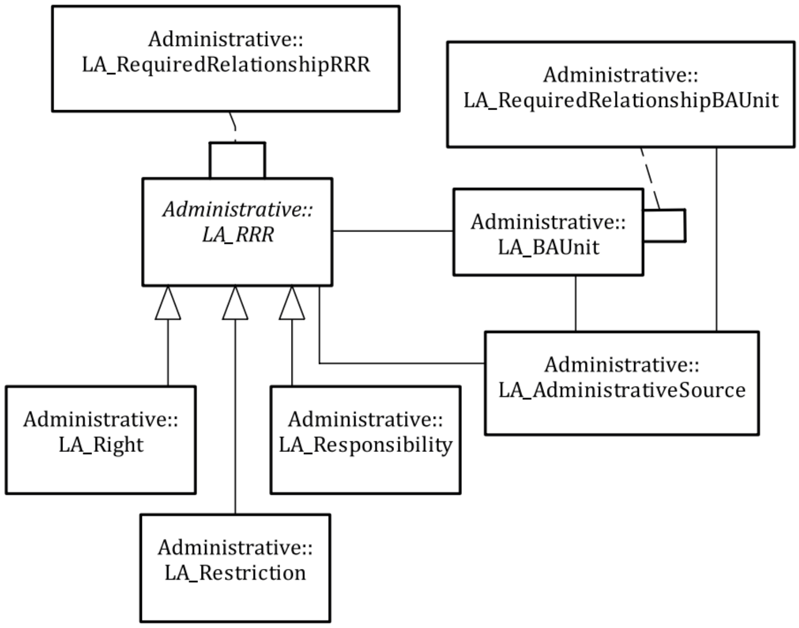


Figure 2.5: Classes of the Administrative package [Kara et al., 2024]

Spatial Unit package The main class of the Spatial Unit package is the basic class LA_SpatialUnit, with spatial units as instances. LA_Parcel is an alias for LA_SpatialUnit. Spatial units may be grouped into two forms:

1. As spatial unit groups, as instances of class LA_SpatialUnitGroup. An example of a spatial unit group is a municipality.
2. As sub-spatial units, that is, a grouping of a spatial unit into its parts. This is realized by an aggregation relationship of LA_SpatialUnit onto itself. In their turn, parts may be grouped into subparts, and so on.

An instance of LA_Level is a level. A level is a collection of spatial units with a geometric and/or topological and/or thematic coherence. Furthermore, required relationships explicitly describe the spatial relationship between spatial units, and instances of class LA_RequiredRelationshipSpatialUnit without reference to geometry. These explicit relationships may be needed, for example when the geometry of spatial units is not accurate enough.

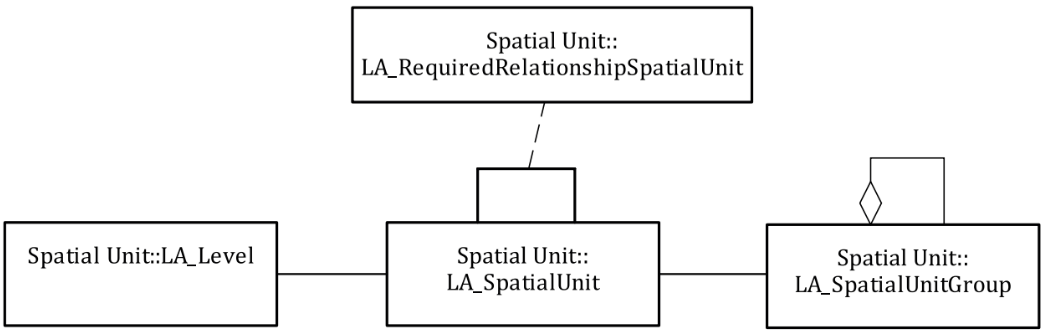


Figure 2.6: Classes of the Spatial Unit package [Kara et al., 2024]

Generic Conceptual Model package The main classes of the Generic Conceptual Model package are the basic classes VersionedObject and LA_Source, see Figure 2.3. The VersionedObject class manages and maintains historical data. The LA_Source class supports any type of source, and represents the event that causes the changes in the register. All classes introduced in this report are directly or indirectly subclasses of VersionedObject, with the exception of LA_Source and its subclass LA_AdministrativeSource.

2.1.2. Part 2 - Land Registration

The information in this section is retrieved from the ISO overview document for Part 2 - Land registration [ISO/TC 19112-2, 2023]. This documentation is in the DIS (Draft International Standard) stage, which means that the document is circulated to all ISO/TC211 P-members members to vote and comment on it. If the DIS is approved, it goes to FDIS (Final Draft International Standard) for a final approval vote, before being published as standard. This is the most up to date document available regarding Part 2 of LADM, when writing this thesis.

Terms and definitions For the purpose of this documentation, the following terms and definitions apply, as well as the terms and definitions defined in the previous section.

Term	*Definition*	*Note to entry*
Administrative source	A source with the administrative description of the parties involved, the rights, restrictions, and responsibilities created and the basic administrative units affected.	
Boundary	A set that represents the limit of an entity.	
Boundary face	A face that is used in the 3-dimensional representation of a boundary of a spatial unit.	
Boundary face string	A boundary forming part of the outside of a spatial unit.	Boundary face strings are used to represent the boundaries of spatial units by means of line strings in 2D.
Face	2-dimensional topological primitive in 3D space.	
Level	A set of spatial units, with a geometric, and/or topological, and/or thematic coherence.	
Point	0-dimensional geometric primitive, representing a position.	May be used to define one or more boundary faces or boundary face string.
Spatial source	A source with the spatial description of the spatial information related to land parcels.	A spatial source (survey or design) may be official, or not (i.e., a registered survey plan, or an aerial photograph).
Utility network	Network describing the legal space of the topology of a utility.	

Part 2 about land registration entails detailed descriptions about the classes introduced in Part 1, and introduces the Survey and Representation sub-package, which includes a new class LA_SpatialSource, as well as support for different observation types, accompanied by several new features and corresponding code lists [Van Oosterom et al., 2022][Body et al., 2022]. The concept of 'integrated source' is introduced and modelled as an association between the Administrative and Spatial Source classes. A semantically enriched, structured and versioned code list is also part of the refinement. Part 2 together with Part 1, form the core of LADM. Figure 2.7 shows the packages of core LADM with their classes and relationships. Figure 2.8 and 2.9 show the packages are defined in which part of the standard.

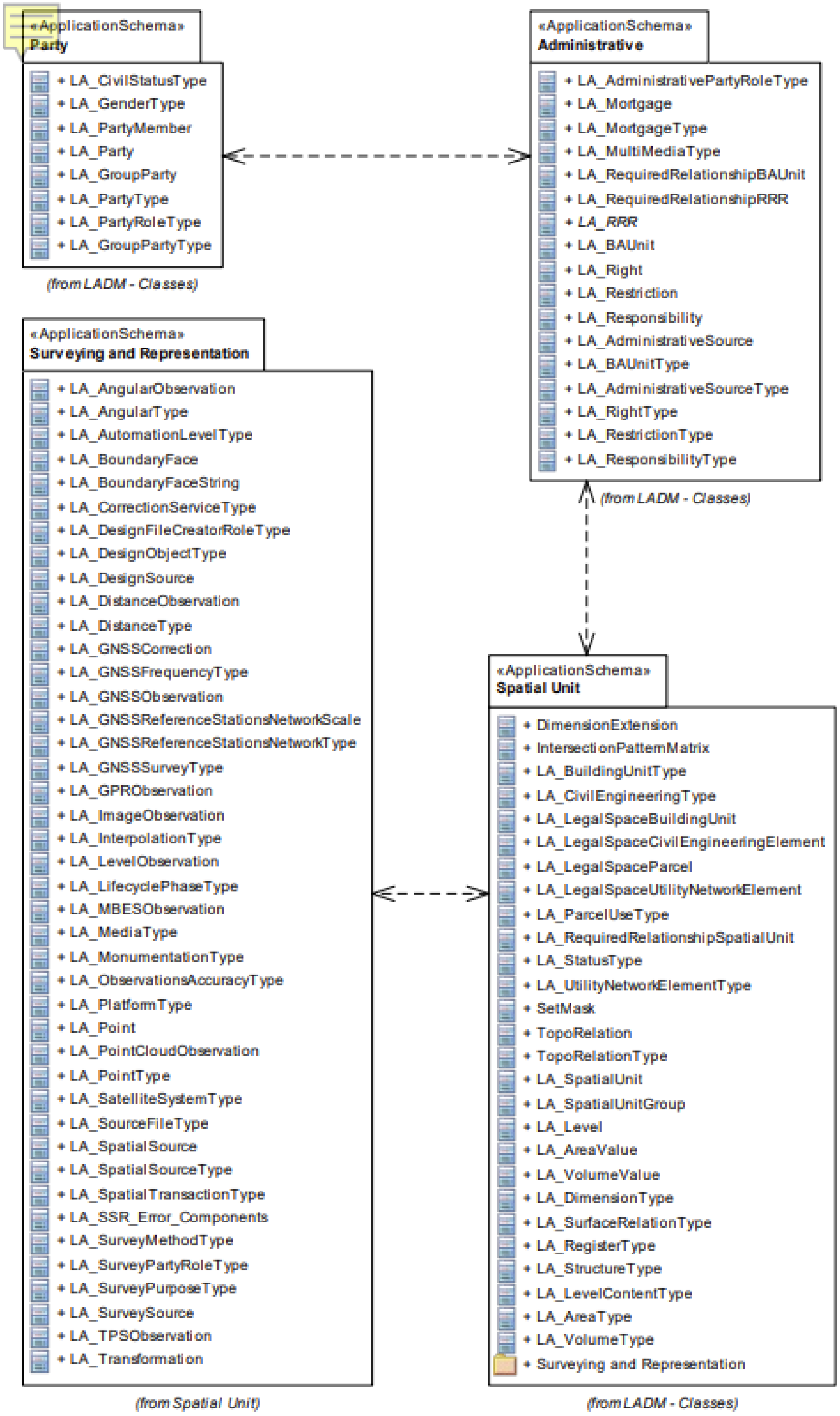


Figure 2.7: Packages, classes and relationships of core LADM [ISO/TC 19112-2, 2023]

(Sub)Package name	Class name	Defined part
Special classes	LA_Source, VersionedObject, Oid, Fraction	Part 1
	—	Part 2
Party	LA_Party, LA_GroupParty, LA_PartyMember	Part 1
	—	Part 2
Administrative	LA_BAUnit, LA_RRR, LA_Right, LA_Restriction, LA_Responsibility, LA_AdministrativeSource, LA_RequiredRelationshipBAUnit, LA_RequiredRelationshipRRR	Part 1
	LA_Mortgage	Part 2
Administrative	LA_BAUnit, LA_RRR, LA_Right, LA_Restriction, LA_Responsibility, LA_AdministrativeSource, LA_RequiredRelationshipBAUnit and LA_RequiredRelationshipRRR	
Spatial unit	LA_SpatialUnit, LA_SpatialUnitGroup, LA_Level, LA_RequiredRelationshipSpatialUnit	Part 1
	LA_LegalSpaceParcel, LA_LegalSpaceBuildingUnit, LA_LegalSpaceUtilityNetworkElement, LA_LegalSpaceCivilEngineeringElement, LA_AreaValue, LA_VolumeValue	Part 2
Surveying and representation	—	Part 1
	LA_Point, LA_BoundaryFace, LA_BoundaryFaceString, LA_SpatialSource, LA_SurveySource, LA_DesignSource, LA_AngularObservation, LA_DistanceObservation, LA_GNSSObservation, LA_GNSSCorrection, LA_GPRObservation, LA_ImageObservation, LA_LevelObservation, LA_MBESObservation, LA_PointCloudObservation, LA_TPSObservation, LA_SSR_Error_Components, LA_Transformation	Part 2
	19152-4	

Figure 2.8: Packages and classes of core LADM [ISO/TC 19112-2, 2023]

(Sub)Package name	**Code list name**	**Defined part**
Special classes	LA_AvailabilityStatusType	Part 1
	—	Part 2
Party	—	Part 1
	LA_PartyType, LA_PartyRoleType, LA_HumanSexesType, LA_CivilStatusType, LA_GroupPartyType	Part 2
Administrative	—	Part 1
	LA_BAUnitType, LA_AdministrativeSourceType, LA_RightType, LA_RestrictionType, LA_ResponsibilityType, LA_MortgageType, LA_MultiMediaType	Part 2
Spatial unit	—	Part 1
	LA_DimensionType, LA_SurfaceRelationType, LA_RegisterType, LA_StructureType, LA_LevelContentType, LA_AreaType, LA_VolumeType, LA_BuildingUnitType, LA_CivilEngineeringType, LA_ParcelUseType, LA_StatusType, LA_UtilityNetworkElementType, TopoRelation, DimensionExtension, SetMask, TopoRelationType	Part 2
Surveying and representation	—	Part 1
	LA_AngularType, LA_AutomationLevelType, LA_CorrectionServiceType, LA_DesignFileCreatorRoleType, LA_DesignObjectType, LA_DistanceType, LA_GNSSCorrection, LA_GNSSFrequencyType, LA_GNSSReferenceStationsNetworkScale, LA_GNSSReferenceStationsNetworkType, LA_GNSSSurveyType, LA_InterpolationType, LA_LifecyclePhaseType, LA_MediaType, LA_MonumentationType, LA_ObservationsAccuracyType, LA_PlatformType, LA_PointType, LA_SatelliteSystemType, LA_SourceFileType, LA_SpatialSourceType, LA_SpatialTransactionType, LA_SurveyMethodType, LA_SurveyPurposeType	Part 2

Figure 2.9: Packages and code lists of core LADM [ISO/TC 19112-2, 2023]

Surveying and Representation package The Surveying and Representation package has sixteen main classes as can be seen in Figure 2.10.

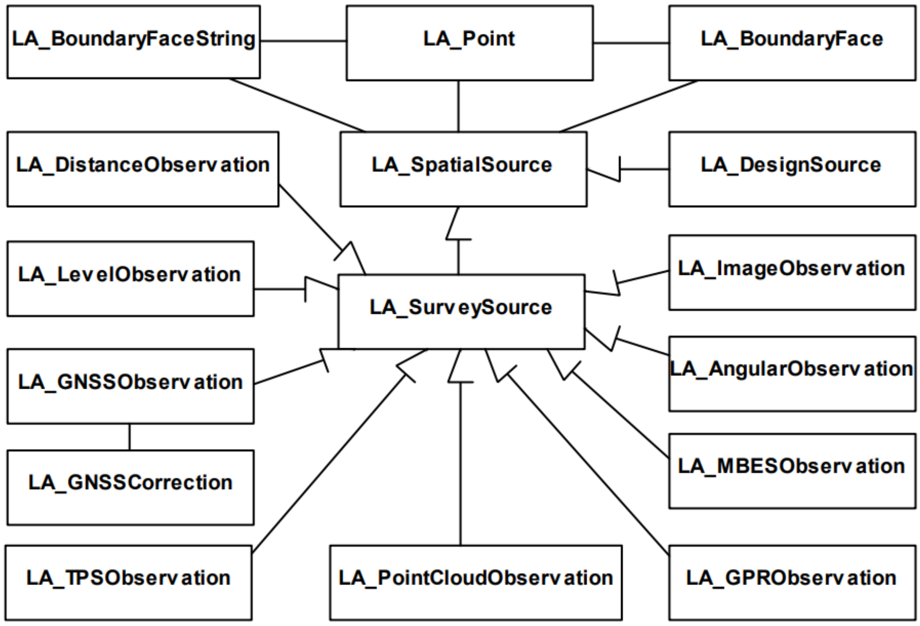


Figure 2.10: Classes of the Surveying and Representation package [Kara et al., 2024]

Individual points are instances of class LA_Point and are associated to LA_SpatialSource. The LA_SpatialSource class is updated and extended with two subclasses: LA_SurveySource and LA_DesignSource. A survey is documented with survey sources, as instances from class LA_SurveySource, this are all documents related to a survey. A design document is documented with design sources, as instances from class LA_DesignSource. Boundary face strings are used for 2-dimensional representations of spatial units, as instances of class LA_BoundaryFaceString, and boundary faces as instances from class LA_BoundaryFace.

2.1.3. Part 4 - Valuation Information

The information in this subsection is retrieved from the ISO overview document for Part 4 - Valuation Information [ISO/TC 19112-4, 2023]. This documentation is in the DIS (Draft International Standard) stage. This is the most up to date document available regarding Part 4 of LADM, when writing this thesis.

Terms and definitions For the purpose of this documentation, the following terms and definitions apply, as well as the terms and definitions defined in the previous sections.

Term	*Definition*	*Note to entry*
Condominium unit	Concurrent ownership of real property that has been divided into private and common portions, and the privately owned part is made up of clearly demarcated parts of a building.	
Accessed value	Monetary worth of property.	The assessed value of a property generally used for tax purposes.
Building	Construction works that has the provision of shelter for its occupants or contents as one of its main purposes, usually partially or totally enclosed and designed to stand permanently in one place.	
Transaction price	Amount of consideration for transferring right(s) on property, excluding amounts collected on behalf of third parties.	
Valuation	Process of estimating value of any administrative unit (BAUnit).	This results in a valuation unit.
Value	Value of a property or a property unit estimated under certain assumptions at a particular moment of time.	A property or a property unit may have more than one value. The value of a property or a property unit, in some cases, may equal to assessed value or market value.
Valuation unit	Smallest unit that is subject to property valuation process.	Valuation unit types may vary by jurisdiction.
Valuation unit group	Group of valuation units that share similar characteristics to support mass or individual appraisal approaches and sale statistics.	Valuation units may be grouped according to zones that have similar environmental and economic characteristics, or considering the functions.

Part 4 specifies the semantics and characteristics of valuation information [Kara et al., 2021]. The valuation model is a conceptual scheme that facilitates all stages of administrative property valuation [Body et al., 2022]. In particular, the identification of properties, the valuation of properties, the recording of the transaction price and the presentation of sales statistics, and finally the handling of appeals [Kara et al., 2021]. This all includes the input and output data in valuation processes [Body et al., 2022].

This part about valuation information is developed through extending core LADM. The relationship between core LADM and Part 4 - Valuation information is organized into a set of packages as can be seen in Figure 2.11. Part 4 about valuation information contains 10 basic classes as shown in Figure 2.12. These main classes are: VM_ValuationUnit, VM_SpatialUnit, VM_Building, VM_CondominiumUnit and VM_ValuationUnitGroup. These classes represent their characteristics and objects of valuation [Kara et al., 2021]. The relationship between these classes and core LADM is visualized in a UML model as can be seen in Figure 2.13.

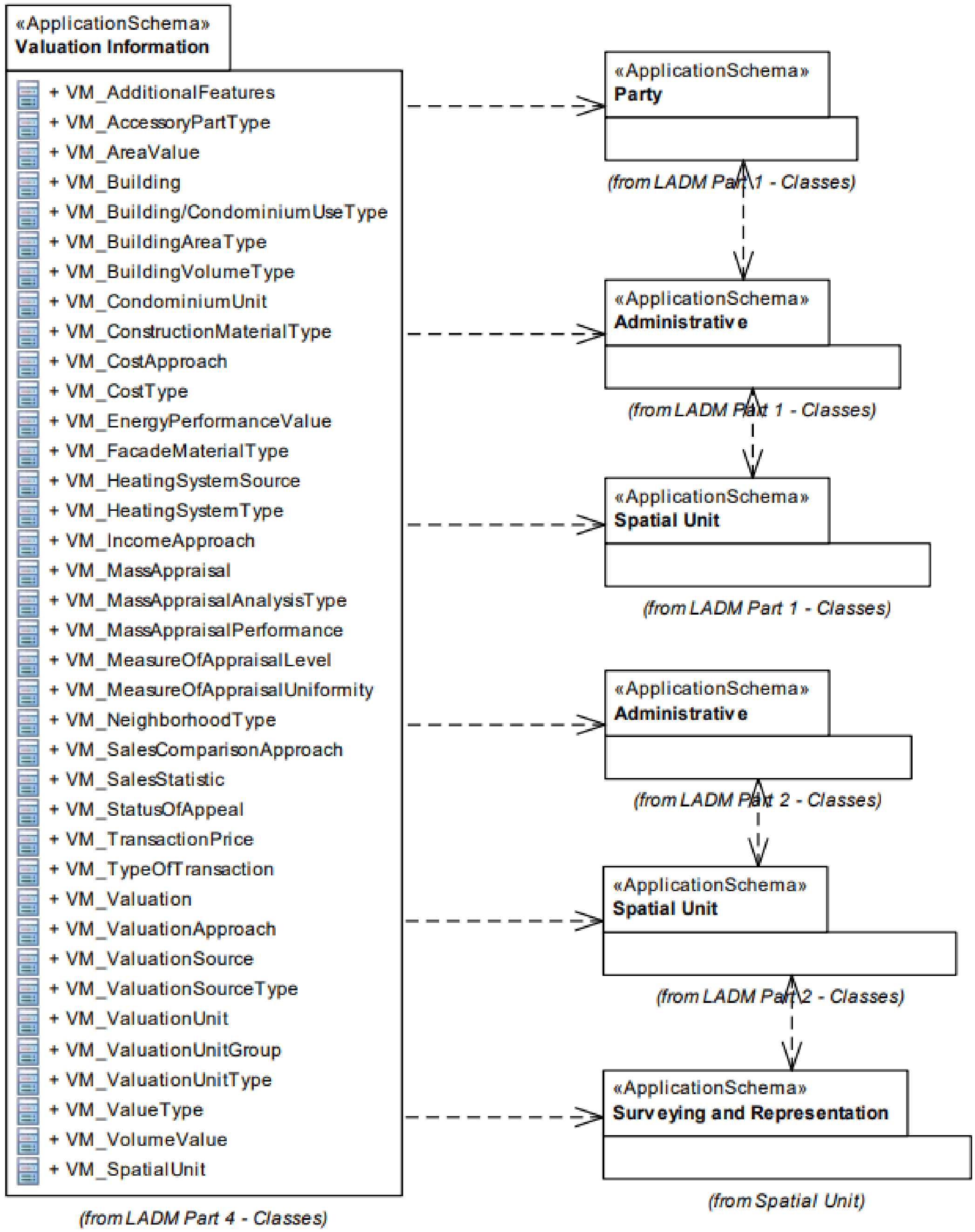


Figure 2.11: Relationships between the valuation information package and the packages of core LADM [ISO/TC 19112-4, 2023]

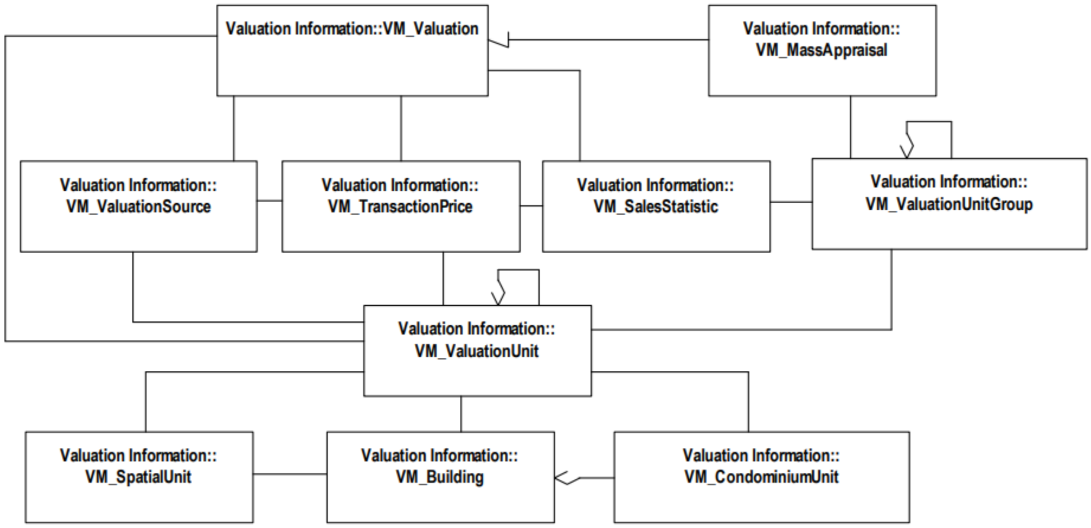


Figure 2.12: Basic classes of valuation information [Kara et al., 2024]

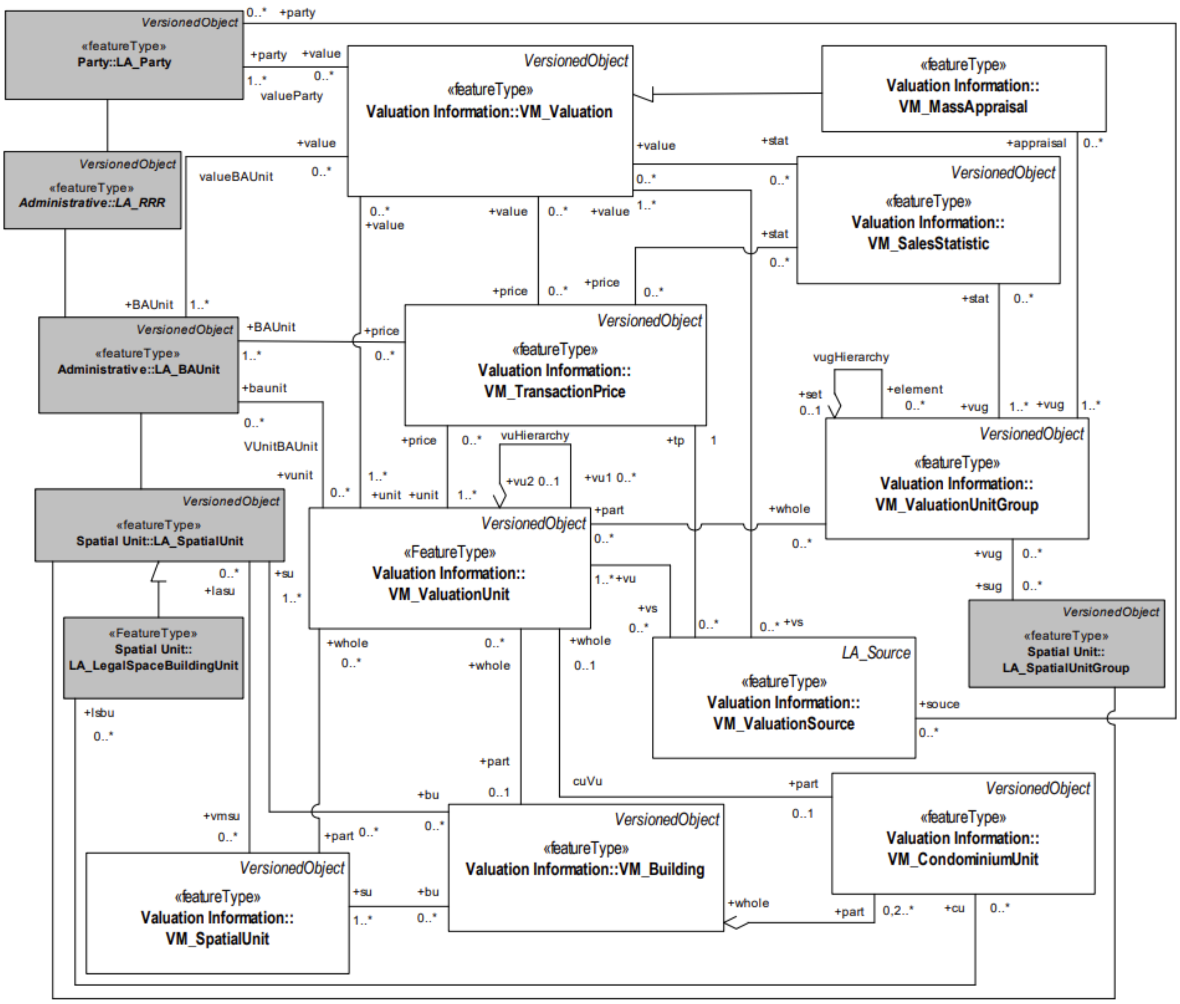


Figure 2.13: Relationships between valuation information classes and core LADM [Kara et al., 2024]

Valuation units, as instances of VM_ValutionUnit, are the basic recording units of valuation registers, realised by an aggregation relationship of VM_ValuationUnit onto itself. The object of valuation may be:

- Only land parcel.
- Only building.
- Land parcel(s) with building(s) together as land property.
- Condominium unit consisting of building(s) and a share in land parcel(s).

Valuation unit groups, as instances of VM_ValuationUnitGroup, are realised by an aggregation relation of VM_ValuationUnitGroup onto itself and may consists of other valuation unit groups.

The class VM_Building includes the building characteristics required in valuation processes (e.g. date of construction, use type and energy performance). A building may be considered as a complementary part of parcel(s), defined in the class VM_SpatialUnit, but may be valued separately from the parcels on which they are located. A building may represent a condominium building, which consists of:

- Condominium units.
- Accessory parts assigned for exclusive use.
- Joint facilities covering parcel, structural components, accession areas, and other remaining areas of buildings.

The class VM_Valuation specifies output data produced within the valuation processes. It is data regarding date of valuation, value type, purpose of valuation, valuation approach, and assessed value of valuation units. Mass appraisal is the process of valuing a group of valuation units using standardized procedures at a given date. The class VM_TransactionPrice defines data of transaction contractor declarations, including the date of contract or declaration, transaction price, date, and type of transaction. The class VM_SaleStatistics represents sales statistics produced through the analysis of transaction prices. In principle property valuation is based on a valuation source, as instances from class LA_ValuationSource.

2.1.4. Part 5 - Spatial Plan Information

The information in this subsection is retrieved from the ISO overview document for Part 5 - Spatial plan information [ISO/TC 19112-5, 2023]. This documentation is in the DIS (Draft International Standard) stage. This is the most up to date document available regarding Part 5 of LADM, when writing this thesis.

Terms and definitions For the purpose of this documentation, the following terms and definitions apply, as well as the terms and definitions defined in the previous sections.

Term	*Definition*	*Note to entry*
Permit	Explicit proof of a right (to perform a task) granted by authorities and granted to parties fitting within the relevant plan unit, that is, the object having the correct function for the requested location.	
Plan unit	Homogeneous area/space (2D/3D) with assigned function/purpose to represent the potential land use development according to the spatial planning authorities at the highest detail, usually the municipality/neighbourhood level.	
Spatial plan	Set of documents that indicates a strategic direction for the development of a given geographic area.	A spatial plan states the policies, priorities, programmes and land allocations that will implement the strategic direction and influences the distribution of people and activities in spaces of various scales.
Spatial planning authority	Authority mandated by the government to design, develop and implement spatial plans.	

Part 5 defines a general schema for spatial plan information. It proposes planned land use to be converted into rights, restrictions, and responsibilities (RRR) [Van Oosterom et al., 2022]. It contains three main classes: SP_PlanBlock, SP_PlanUnit, and SP_PlanGroup [Lemmen et al., 2019]. The LA_SpatialUnit is used in this part to facilitate RRRs from land administration and spatial planning processes.

The spatial plan information package includes planned land use (zoning) to be converted into RRRs. The spatial plan information information includes five basic classes, see Figure 2.14:

1. SP_PlanUnit
2. SP_PlanBlock
3. SP_PlanGroup
4. SP_PlanUnitGroup
5. SP_Permit

The package accommodates hierarchy (e.g., national/federal, regional/state, municipality/city, neighborhood, and so forth) in spatial planning in SP_PlanGroup.

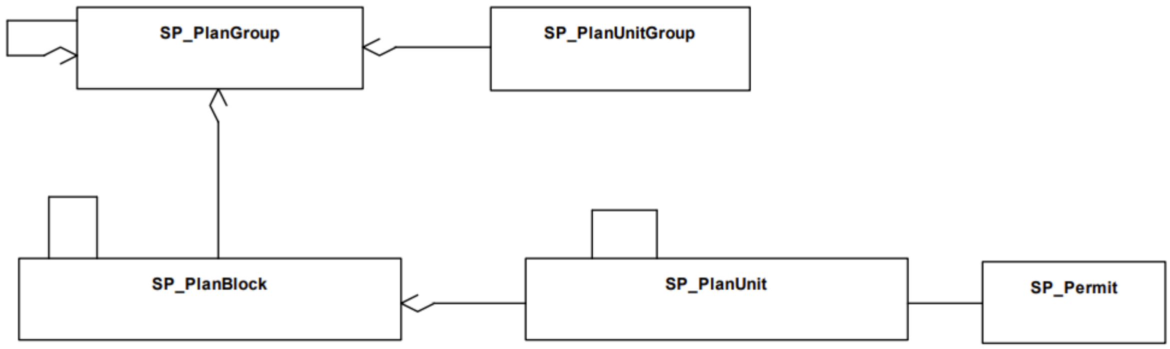


Figure 2.14: Basic classes of spatial plan information [Kara et al., 2024]

The relationship between core LADM and Part 5 - Spatial plan information is organized into a set of packages as illustrated in Figure 2.15. The relationship between spatial plan information and core LADM is also visualized in a UML model as can be seen in Figure 2.16. Figure 2.17 shows the relationship of the class SP_Permit with SP_PlanUnit and core LADM. All spatial plan classes inherit from VersionedObject as can be seen in Figure 2.18.

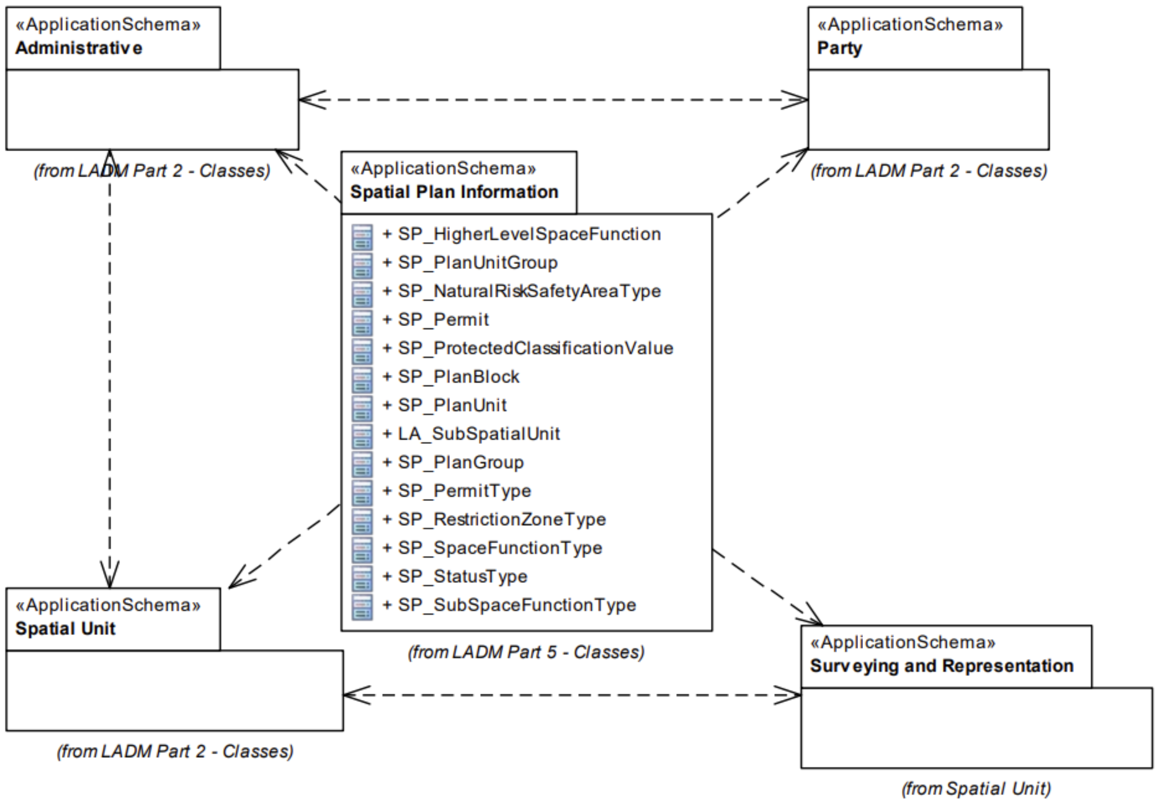


Figure 2.15: Relationships between the spatial plan information package and the packages of core LADM [ISO/TC 19112-5, 2023]

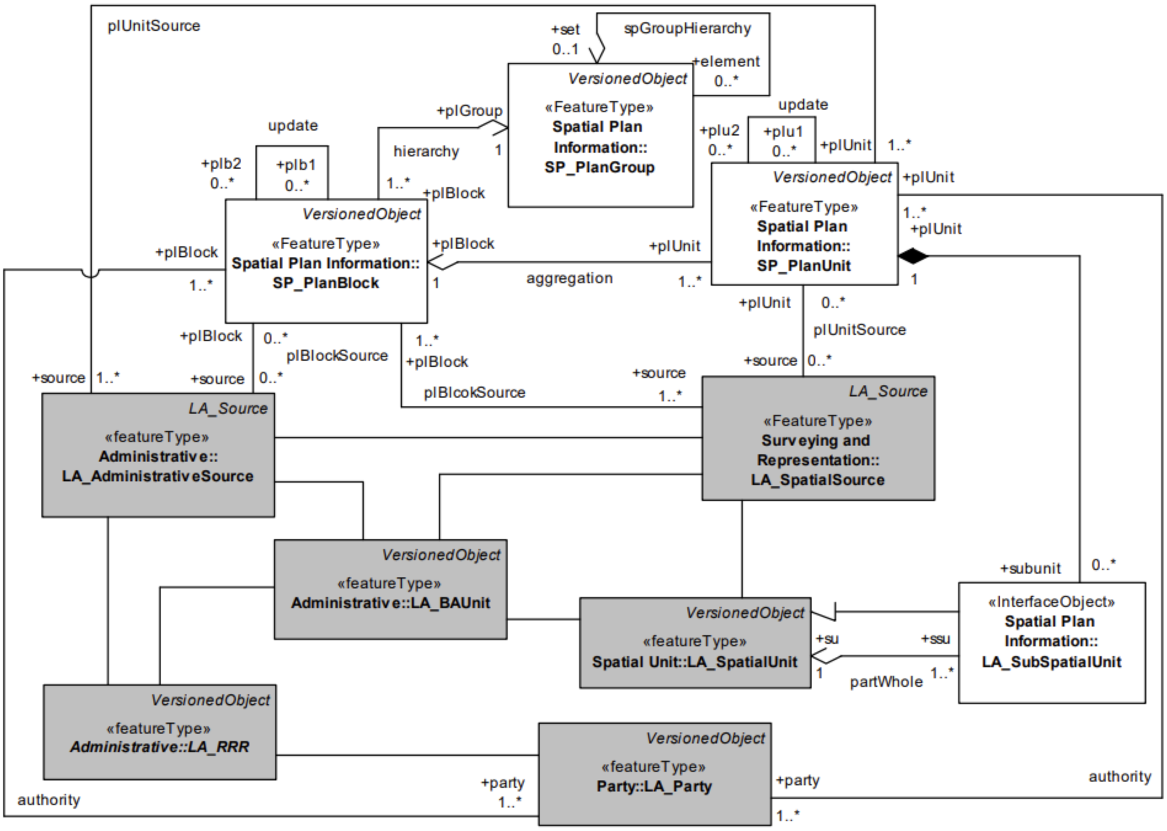


Figure 2.16: Relationships between spatial plan information classes and core LADM [Kara et al., 2024]

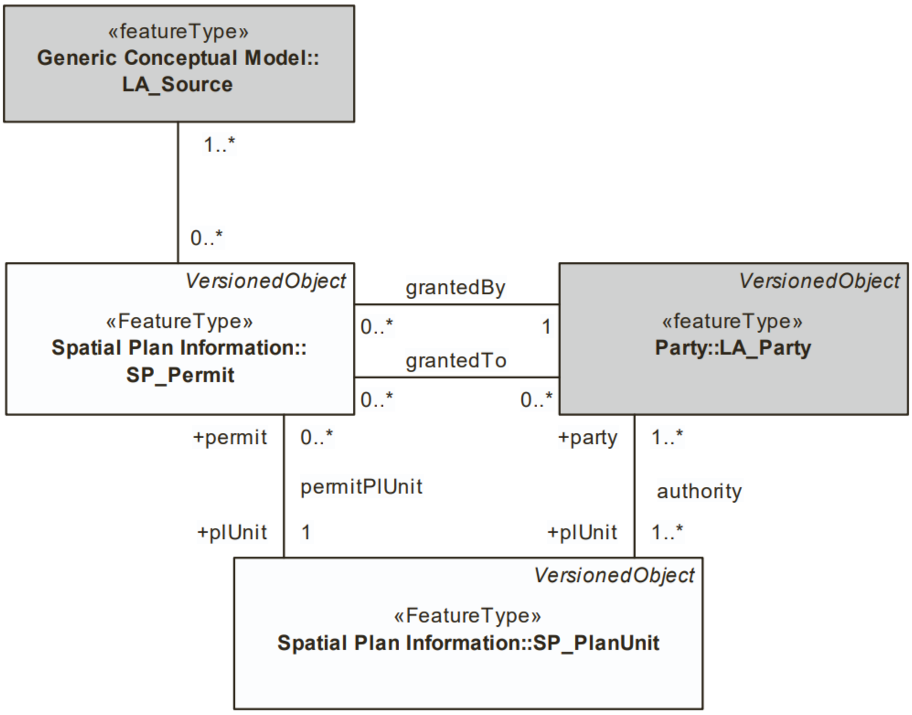


Figure 2.17: SP_Permit and its relationship with SP_PlanUnit and core LADM [Kara et al., 2024]

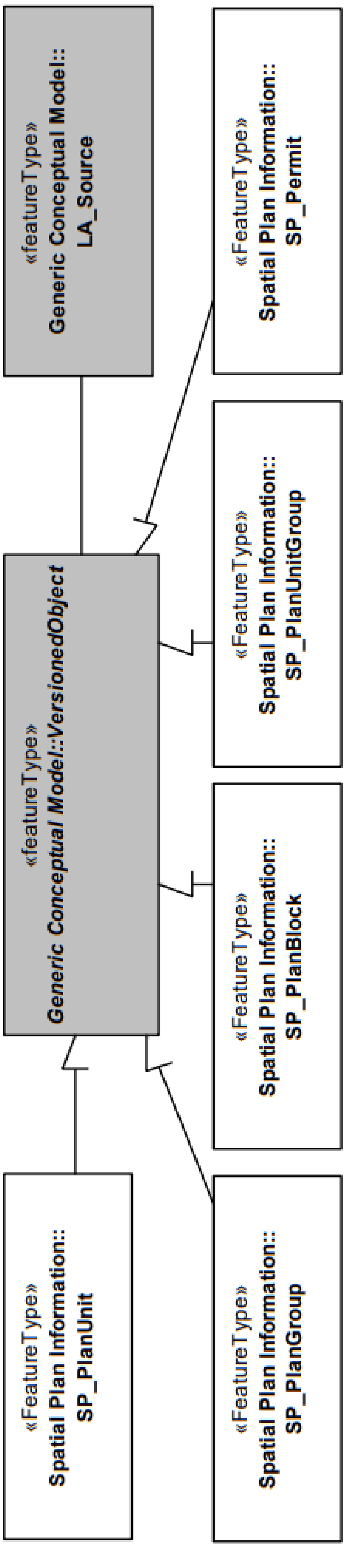


Figure 2.18: Spatial plan information package and VersionedObject [ISO/TC 19112-5, 2023]

2.2. Land administration in the Netherlands

Land administration information in the Netherlands can be accessed through various geoportals. The data in these geoportals are each structured and formatted according to the land registers they include, which leads to cross-sector interoperability problems when trying to link these different LAS [Çağdaş and Stubkjær, 2014]. It is therefore important to have an integrated land administration system that clearly identifies the registered units within the land registers and their attributes, as well as their interrelationships. The following sections describe general information on land registration (see Section 2.2.1), valuation information (see Section 2.2.2) and spatial planning (see Section 2.2.3) in the Netherlands, as well as the required datasets and geoportals.

2.2.1. Land registration in the Netherlands

Land registration in the Netherlands is managed by Kadaster (the Dutch Cadastre, Land Registry and Mapping Agency), an official independent administrative body. Kadaster performs its tasks under the supervision of the Ministry of Housing, Spatial Planning and the Environment (VROM), to ensure legal certainty. The Cadastral Act outlines the responsibilities of the Kadaster, which include maintaining public registers of registered property, updating the base land register, and maintaining and updating registrations for ships and aircraft. The purposes of these tasks are to support legal certainty with regard to registered property, to support an efficient geo-information infrastructure, to support an efficient provision of information to the government for the benefit of public-law tasks and statutory obligations of administrative bodies, and to support economic activity [Bartels et al., 2021].

In practise this means that the Kadaster is responsible for cadastral registration, which includes various real estate assets such as parcels and condominium rights. It records detailed information about ownership, mortgage rights, and easements, assigning unique cadastral numbers to each parcel of land to identify specific ownership information. The Kadaster also manages national mapping and maintaining of the national reference system, and cadastral maps used to map the boundaries of parcels and properties. The owner of a particular piece of land or building is also recorded by Kadaster. Furthermore, the Kadaster provides information on mortgage rights and plays a crucial role in spatial planning and urban development. It offers data for drafting spatial plans and managing public spaces. In recent decades, the Kadaster has digitized its processes, making information easily accessible to citizens, businesses, and real estate professionals.

In summary, the Kadaster has several key tasks, including maintaining various registrations such as real estate and topography. They also provide access to information from registrations of other parties and maintain national facilities that provide access to data, such as addresses and buildings, cables and pipelines, and energy labels. Information products are provided through registrations and national facilities in various formats, including data files, formal documents, and maps [Kadaster, ndb].

Required datasets for land registration and their data sources The Netherlands operates a system of base registers that have an important role in organizing and managing essential information across various domains. The 10 base registers in the Netherlands are:

- BRP - Base register of persons
- HR - Commercial Register
- BAG - Base register of Addresses and Buildings
- BRT - Base register of Topographical Information
- BRK - Base land register
- BRV - Base register of Vehicles
- BRI - Base register of Income
- WOZ - Base register of Property Valuation
- BGT - Base register of Large-Scale Topography
- BRO - Base register of Surface

Stakeholders benefit from the effective use of commonly used government data, such as addresses, personal information, company names, and geospatial data. This data is recorded in these base registers, and by sharing known data within the government it can act efficiently. The system sheet data, see Figure 2.19, illustrates the data and their interconnections. In addition, there is a system sheet for base registers which focuses on the 10 base registers and their interconnections, see Figure 2.20.

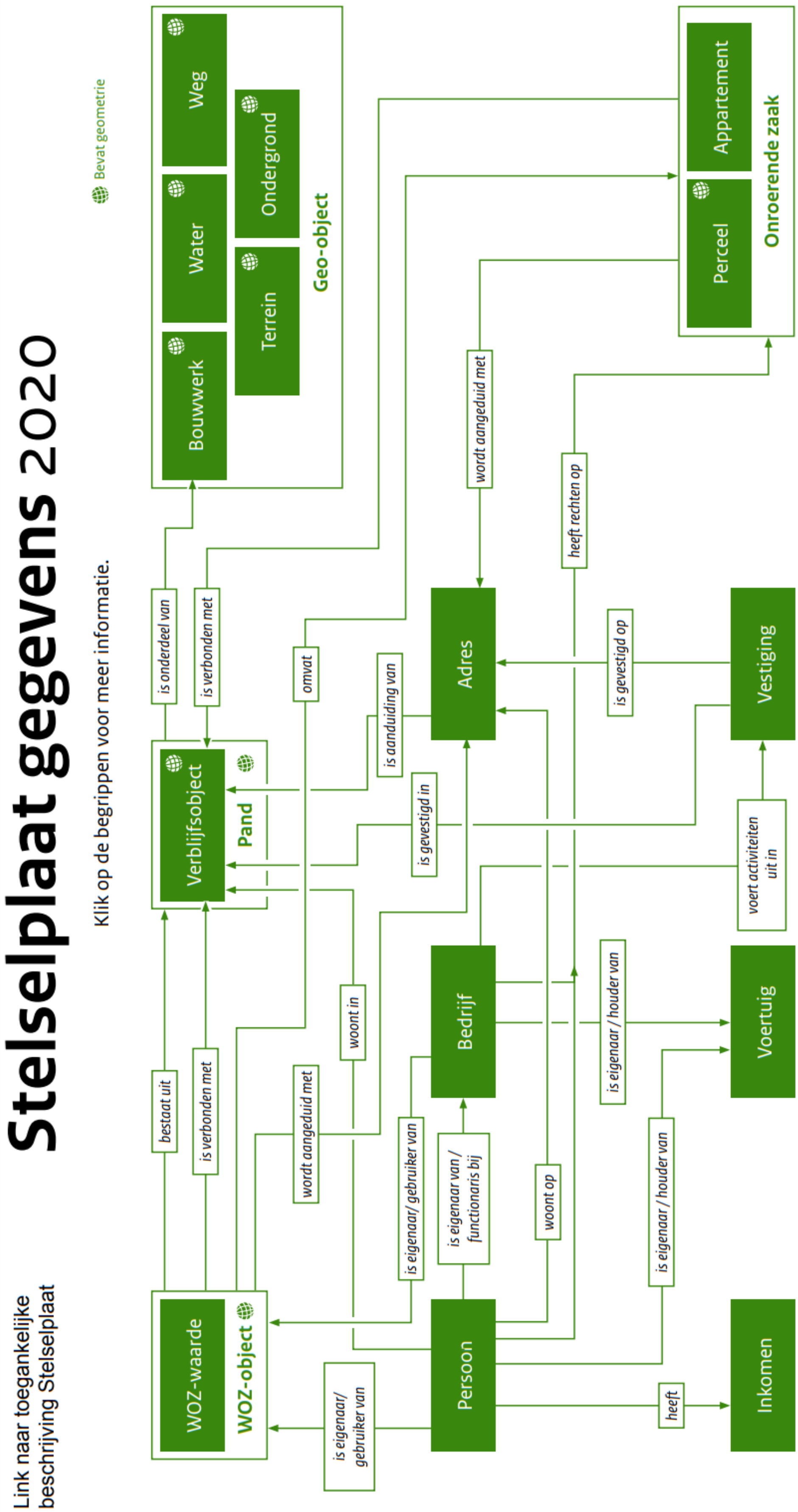


Figure 2.19: System sheet of data in the Netherlands [Overheid, 2020b]

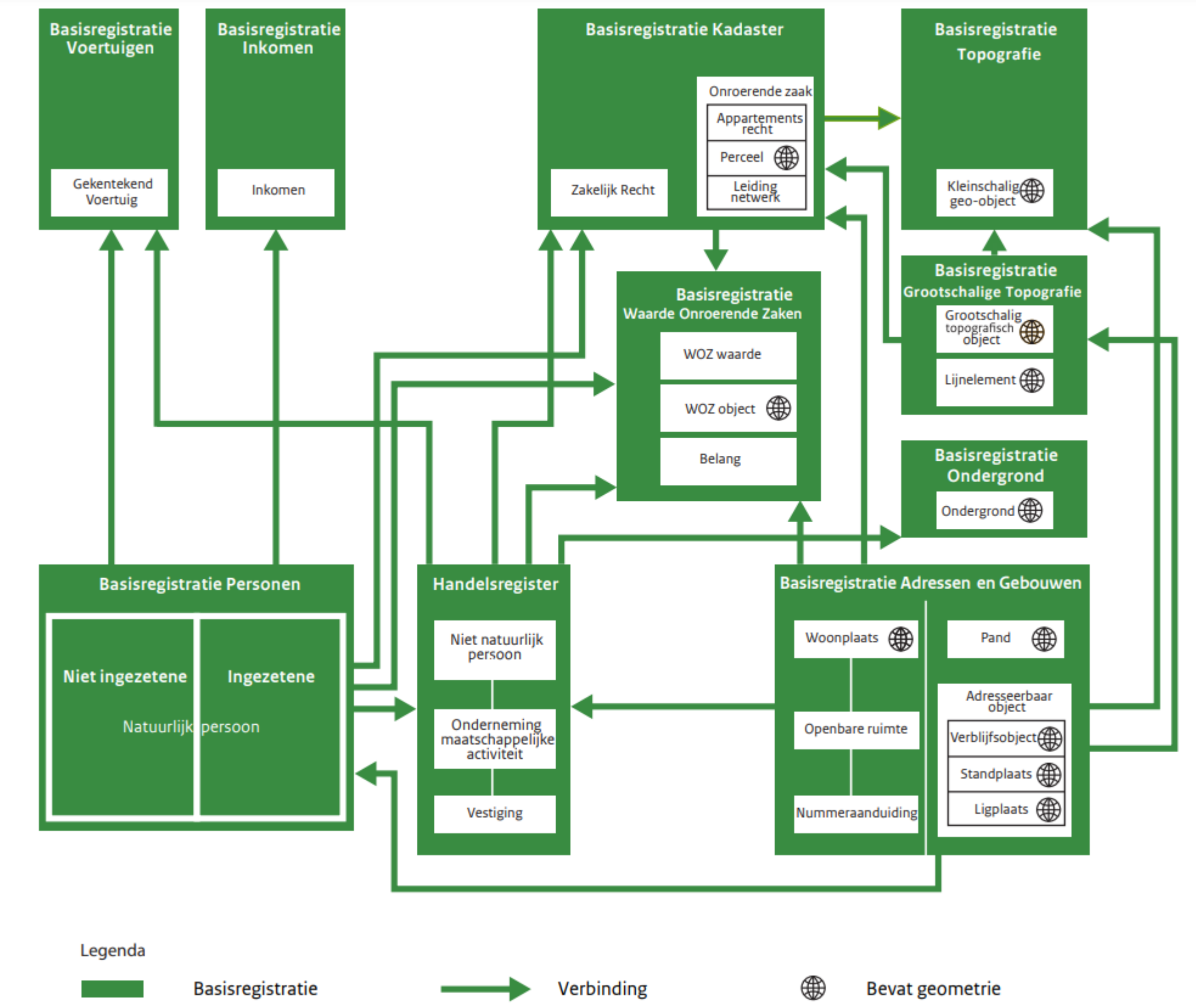


Figure 2.20: System sheet of base registers in the Netherlands [Overheid, 2020a]

The most relevant base registers to this study BRP, HR, BAG, BRT, BRK, BGT and WOZ are described in the following.

The BRP is managed by the government, by extracting information from municipal base registers. Data in the BRP is protected and therefore not publicly accessible. However, citizens can request it from their municipality. The HR is managed by the Chamber of Commerce (KvK) and data in the HR is publicly accessible through the KvK website, where citizens and companies can access company data and legal entity registrations.

The Kadaster manages the BAG and collects information from municipalities. Data from the BAG can be viewed through the BAGviewer, this is an online environment that provides access to all official addresses, buildings, residential units, stands, and berths assigned on Dutch territory.

The Kadaster also manages the BRT and often collaborates with other organizations, such as the Ministry of Infrastructure and Water Management, to collect data. The BRT data can be accessed through the PDOK platform.

The BRK is managed by Kadaster by extracting information from legal documents, including notarial deeds, delivery deeds, and mortgage deeds. The BRK can be accessed via the website of Kadaster, additionally PDOK also offers BRK data.

The Kadaster is also responsible for the management of the BGT and collects data on large-scale topography of the Netherlands, often in collaboration with other parties.

Finally, municipal tax authorities determine the value of immovable property based on appraisals and market analyses to administer the WOZ value. The WOZ value is also publicly available and can be viewed thought the online web environment of Wozwaardeloket.

Bagviewer The Bagviewer geoportal represents data from the base register of addresses and buildings (BAG). which includes all official addresses, buildings, residential units, stands (for residential caravans), and berths (for ships) assigned on Dutch territory [Kadaster, nda]. Specific object types and attribute values are defined in the Bagviewer. Known object types in BAGviewer are:

- Number designation.
- Public space.
- Residence.
- Property.
- Accommodation.
- Stand.
- Berth.

Municipalities are responsible for maintaining the BAG as source holders, including the addition and quality of data. The National Provision BAG (LV BAG) centrally provides data on addresses and buildings. The Kadaster offers this data to various users in different ways, such as through PDOK and the Bagviewer. The viewer offers background maps from the BRT, BGT, and aerial photographs. Moreover, users can download data by selecting desired objects and attributes, and exporting them as a PDF. The Bagviewer also provides a glossary that defines and describes technical terms and their abbreviations.

2.2.2. Valuation information in the Netherlands

The WOZ value is the market value of a property on a specific date. It is formally assessed annually for all types of properties in the Netherlands. The Special Act for Real Estate Assessment (Wet Waardering Onroerende Zaken) regulates property valuation for public purposes. The Act authorises all municipalities to assess the value of immovable properties. Public organisations are mandated to use these assessed values for various purposes. The Council for Real Estate Assessment (Waarderingskamer) supervises the municipalities on the implementation of the Act and monitors the quality of real estate property assessment [Kathman and Kuijper, 2018]. The WOZ value is used for various purposes, including mortgage lending, social housing, and fraud prevention. Notaries, mortgage banks, and insurance companies also use the WOZ value to prevent real estate fraud. The WOZ values for residential properties are publicly available through the online environment Wozwaardeloket [Rijksoverheid, nd], which is discussed later in this section.

Required datasets for valuation information and their data sources Three types of data sources are used by the municipalities responsible for property valuation in the Netherlands. These data sources are the base registers, information from the system for advertising the supply of real estate on the market, and information that the municipality collects specifically for mass valuation [Kathman and Kuijper, 2018]. Base registers are intended for official use by public agencies at both central and local levels. The base register for assessed values provides information on the WOZ value, valuation date, valuation object (WOZ-object), and legal person. The base register has relations with the objects in the BRK and the BAG. The BRK is essential for property valuation as it records the ownership of parcels of land and apartment rights and is therefore the main source of information for establishing the list of properties to be assessed for taxation. The BRK also provides information on the size of cadastral parcels, which is utilized in property valuation activities. Additionally, this register contains information on sale prices for both residential and non-residential properties. The BAG contains information on buildings, occupancy units in building and their addresses. All source documents relating to administrative or geometric changes to a building and an occupancy unit must also be stored in the BAG register.

Other registers commonly used in property valuation include the BGT, BRP, and HR. The BGT provides information on the construction year of buildings and the size of property units, which can be used in property valuation and geographical analysis to determine the value of immovable properties. The BRP contains personal data of both residents and non-residents of the Netherlands and is used to determine taxpayers. Similarly, the commercial register is used for legal persons such as companies.

Wozwaardeloket The Wozwaardeloket geoportal contains information on the Waardering Ontroerende Zaken (WOZ) (Base register of real estate values) [Rijksoverheid, nd]. The WOZ value is the estimated market value of a property determined on the assessment date. The Wozwaardeloket is intended for consultation of individual houses for citizens and not for mass or automated downloading and/or extraction of data. Municipalities are the source holders of the data and must provide it annually. The Council for Real Estate Assessment (Waarderingskamer) is an independent administrative body that oversees the taxation, the Wozwaardeloket geoportal itself is maintained by the government, specifically by the Netherlands Enterprise Agency (RVO) which is an implementing organisation of the Ministry of Economic Affairs and Climate. In addition to the WOZ values, the platform displays the following data:

- Identification (WOZ-object number).
- Use purpose.
- Attributes: (from the base register of addresses and buildings (BAG))
  - Year of construction.
  - Purpose of use.
  - Surface area.
  - Addressable object.
  - Number designation.

A user can find information about a property by, searching an address, clicking on an element on the map, filtering in the properties visible on the map, using map layers, or zooming in and out.

2.2.3. Spatial plan information in the Netherlands

Land use plans are an essential tool in spatial planning. National interests are defined in the Spatial Vision on Infrastructure and Spatial Planning (SVIR). The implementation of spatial plans for the state, provinces, and municipalities is outlined in the Spatial Planning Act (WRO). Spatial visions are policy documents that replace key planning decisions on government level, regional plans on provinces level, and structure plans on municipal level. Spatial plans establish regulations for a given area and include a planning map that illustrates the various zones. Spatial planning decisions are made at national, regional, and local levels based on these plans. Municipalities shape spatial planning policy and implementation, allowing them to establish appropriate regulations based on their local situation [Ministerie van Infrastructuur en Waterstaat, 2017].

The Environment and Planning Act (Omgevingswet) came into force on 1 January 2024. This Act applies to spatial planning including anyone who wishes to make changes to the living environment and determines whether a permit or notification is required. In addition to spatial planning, public law restrictions may apply. Public law restrictions are imposed by the government and specify what someone can or cannot do with a property or piece of land. The Public Law Restrictions on Real Property Act (WKPB) was enacted to provide insight into the restrictions imposed. On the basis of this law, governments must register decisions on public law restrictions in the public register, access to the resistered restrictions is provided by the BRK-PB. A total of 48 restrictions can be found in the public register [Planviewer, nd], the

Designation decree on the Act Public Law Restrictions on Immovable Property (Aanwijzingsbesluit Wet kenbaarheid publiekrechtelijke beperkingen onroerende zaken) lists the restrictions that can and should be registered in the public registers. Public law restrictions are also listed in an owner's report, which can be requested from the BRK for free for the owners, and other entitled parties can request it against payment of a small fee.

Required datasets for spatial plan information and their data sources Spatial plans are created based on the guidelines set out in the SVIR by the government, as well as the zoning plans created by municipalities. The zoning plans for each area can be accessed through the online web environment Omgevingsloket. A zoning plan outlines the permitted and prohibited activities in a given area, while a spatial plan is a comprehensive collection of all spatial plan information for a designated area, usually in PDF format. Spatial plans can be provided in various formats, including Geography Markup Language (GML), GeoJSON, Shapefile, and Keyhole Markup Language (KML).

The BRK contains information on limited rights related to cadastral designation, such as leasehold, superficies and usufruct. The most important sources of public law restrictions are municipalities, provinces, water boards, and the national government. It is important to note that spatial plans are not included in the BRK-PB.

Ruimtelijkeplannen Note: During the writing of this thesis, Ruimtelijkeplannen was the official geoportal for retrieving spatial plans. However, as of 1 January 2024, the Environmental and Planning Act came into force, resulting in the Omgevingsloket becoming the central online web environment for spatial plans and permit applications. Regarding content, it is still relevant to discuss Ruimtelijkeplannen, as the functionality is taken over by Omgevingsloket.

Ruimtelijkeplannen is the result of a collaboration between the national government, Kadaster, Geonovum, Interprovinciaal Overleg and the Association of Dutch municipalities [Rijksoverheid et al., nd]. It serves as the national geoportal for spatial plans, which include zoning plans, structural visions and general rules set by municipalities, provinces and the national government. These plans provide objective information on government spatial planning. The viewer of the geoportal offers various backgrounds for user orientation. These backgrounds and detailed digital maps rely on the base register of topography (BRT) and base register of large-scale topography (BGT) and are displayed using open standards for geographic web services. The geoportal also offers a viewer service to display plan map information. The system offers multiple types of geospatial services, including Web Mapping Service (WMS), Web Feature Service (WFS), and tiled services. Additionally, users have the option to request a plan or point location through a deep link that contains parameters. Furthermore, users may use the print function to save a map image in PDF format.

Municipalities, provinces and the national government are the source holder of data on Ruimtelijkeplannen. They provide spatial plans by offering a complete and validated set of plan files in a manifest. Manifests can be offered in accordance with defined standards. Furthermore, Ruimtelijkeplannen is connected to the geoportal Public Service on the Map (PDOK). This means that spatial plans are also made available via PDOK as WMS or as a download, also multiple map layers of Ruimtelijkeplannen are accessible in the webviewer PDOK [PDOK, 2022].

These map layers include: Area Designation, Letter Designation, Zoning Plan Area, Plan Area, Provincial Complex, Provincial Area, Provincial Plan Area, 9 Decision Areas, and 8 Structure Visions. Note that the spatial plan information in PDOK is updated only once per month. For the most up to date spatial plan information, the PDOK website refers to Ruimtelijkeplannen.

2.3. Country profile

The implementation of LADM in a country involves developing a country profile (e.g. UML application schema) [Kara et al., 2021]. The creation of a country profile based on LADM and efforts to apply LADM on Land Administration Systems (LASs) have so far been carried out by several countries, such as Czech Republic [Janečka and Souček, 2017], Croatia [Mađer et al., 2015] [Vučić et al., 2013], Turkey [Kara et al., 2021], Malaysia [Zulkifli et al., 2015b], China [Zhuo et al., 2015] and Poland [Bydłosz, 2015]. The results of these studies can be used as a guide and example for the creation of a country profile. Previous research proposes a methodology for the development of LADM country profiles, which consists of three phases, including [Kalogianni et al., 2021]:

Phase I Scope definition
Phase II Profile creation (modelling)
Phase III Profile testing (implementation)

Phase I involves defining the model's scope, which encompasses describing the context the model will depict: the LASs, classes, attributes, and code lists. In Phase II the country profile is modelled using UML, based on the analysis from the first phase. In the conceptual modeling, it is recommended to follow the subsequent steps:

1. Inheritance from LADM core classes into the relevant country-specific classes using a prefix denoting the country, or explicit schema mapping between the country profile and LADM classes in case inheritance is not used.
2. Creation of new classes serving the specific needs that are not supported in the LADM, if needed.
3. Adding new attributes to address country-specific needs and requirements.
4. Introducing new associations based on country specific needs.
5. Further restrict to multiplicities according to if needed, and define relevant constraints to be imposed.
6. Adding new values to existing code lists and new code lists, if required, for new attributes.
7. Introducing external classes to link the model with the external registers.
8. Conformity testing.

The final phase involves testing the country profile by translating the UML conceptual model into the respective database schema and implementing it with technical encoding. This proposed methodology of the development of LADM country profiles can serve as a guideline for the development of the country profile of the Netherlands.

2.3.1. The Netherlands

In the first publication of LADM [ISO, 2012], the country profile of the Netherlands was developed, as shown in Figure 2.21. Furthermore previous research resulted in the development of the country profile of the Netherlands for the valuation information model [Kara et al., 2019], as can be seen in Figure 2.22.

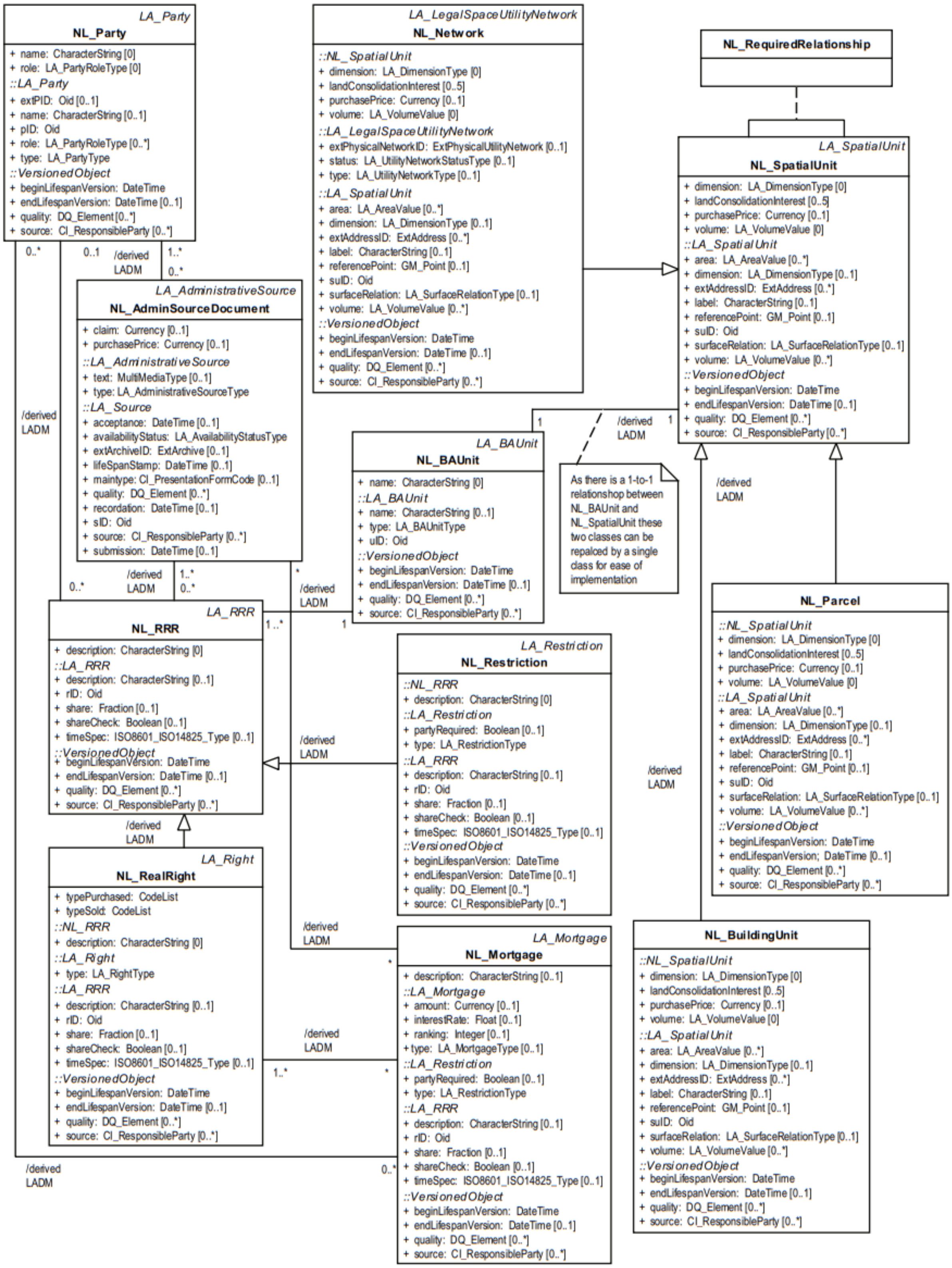


Figure 2.21: Country profile of the Netherlands [ISO, 2012]

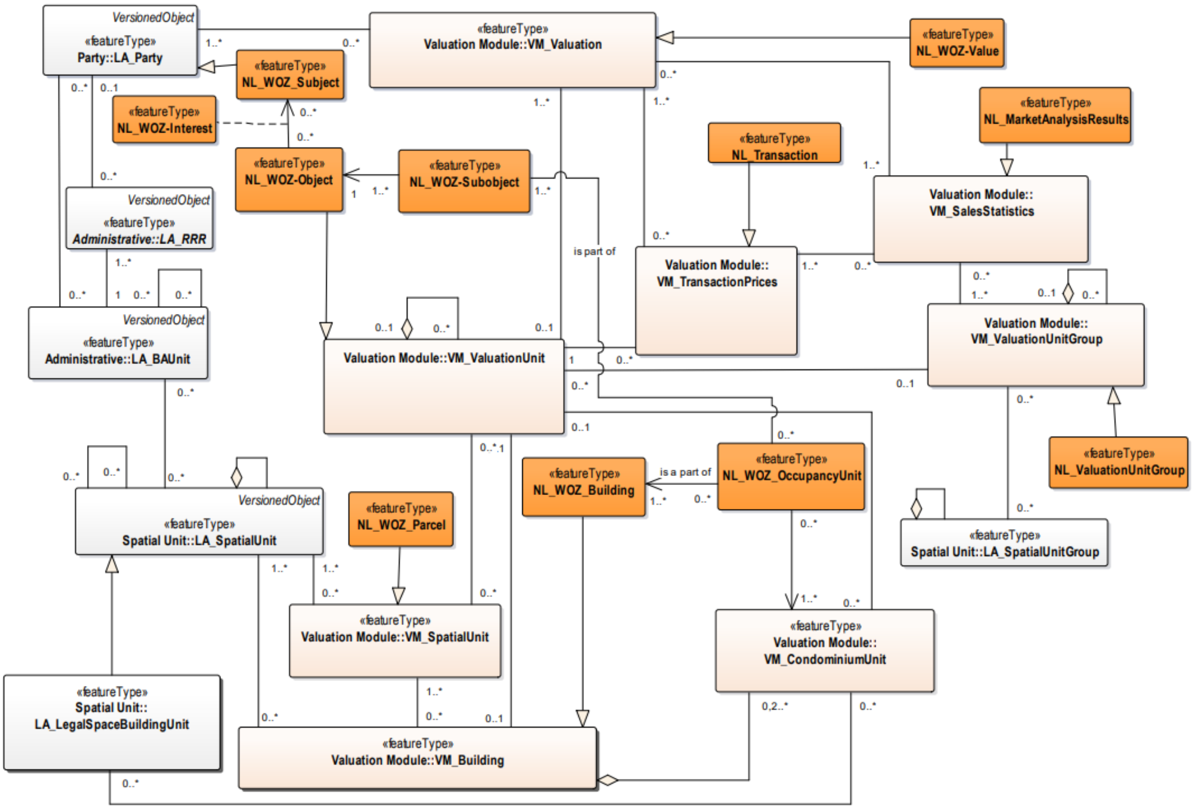


Figure 2.22: Country profile of the Netherlands for the valuation information model [Kara et al., 2019]

2.4. Linked data

As mentioned in the introduction of this study, linked data allows data to be linked and used within an SDI to improve data interoperability and accessibility. Linked data can be a way to implement an LADM-based country profile by establishing relationships between different land registers and geoportals, making it easier to access and navigate data.

Linked data is about using the web to create links between data [Bizer et al., 2009]. More specifically, it is about using the Resource Description Framework (RDF) and the Hypertext Transfer Protocol (HTTP) to link data published on the Web from different sources [Bizer et al., 2008]. Linking data this way allows users to navigate between different land registers by following RDF links. Simply said, an RDF link indicates that a piece of data has some relationship to another piece of data [Bizer et al., 2008]. A defined a set of rules for linked data on the Web is stated [Bizer et al., 2009]:

1. Use Uniform Resource Identifiers (URIs) as names for things.
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up an URI, provide useful information, using the standards (RDF, SPARQL).
4. Include links to other URIs, so that they can discover more things.

Data must be published in RDF links, known as triples, which allow an element to be linked to other elements [Çağdaş and Stubkjær, 2014]. These triples consists of three components:

1. Subject: an URI that represents a thing.
2. Predicate: an URI that indicates the relationship.
3. Object: an URI or literal that identifies another thing.

Figure 2.23 shows an example of an RDF triple where a cadastral parcel (subject) has a cadastral boundary part (object), and its relationship is represented by the boundary itself (predicate).

<http://location.data.eu/so/cp/CadastralParcel/12345><http://cadastralvocabulary.org/land/#boundary><http://location.data.eu/so/cp/CadastralBoundary/67890>

Figure 2.23: Example RDF triple
(subject in blue, predicate in orange, and object in green)

SPARQL is the standardized query language for linked data that allows querying and combining data from multiple datasets [Kadaster, 2013]. In the context of this study, the linked data approach can enable easy integration of land registers, LAS, and geoportals maintained by different organizations. However, this approach requires a Knowledge Organization System (KOS) in the form of controlled vocabularies, taxonomies, thesauri, or ontologies that provide shared descriptions of domain concepts and the relationships between these concepts [Çağdaş and Stubkjær, 2014]. Previous research contributed to the linked data approach by developing a conceptual model and RDF schema that can be used to represent land administration data as linked data [Çağdaş and Stubkjær, 2014]. More details on this research can be found in Appendix A.

2.5. Kadaster Knowledge Graph

As previously mentioned, implementing the linked data approach in a domain requires controlled vocabularies, taxonomies, thesauri or ontologies that describe the domain-specific classes and their relationships, solving semantic interoperability problems. This aspect is critical for semantic resource identification, classification, and the shared description of domain concepts and their relationships [Çağdaş and Stubkjær, 2015]. One method to accomplish this is through the use of a knowledge model.

A knowledge model is a collection of interlinked descriptions of concepts, entities and relationships of general world knowledge [Ronzhin et al., 2019]. A Knowledge Graph (KG) contextualizes data through linking semantic metadata, presenting a network of real world entities and their relationships. This information is typically stored in a graph database and visualized in a graph structure, hence the name Knowledge 'Graph'. A KG comprises three primary components:

Nodes Any object, person or place.
Edges Defines the relationship between two nodes.
Labels To classify nodes.

This structure may seem familiar since KGs are represented in an RDF. As previously explained in Section 2.4, this framework illustrates the relationships between entities using triples comprising a subject, predicate, and object. Utilizing a KG as a foundation and subsequently employing the linked data approach in a particular domain could prove to be an effective method.

In most cases, KGs are constructed from datasets originating from diverse sources, often with varying structures. The structure of a KG is formed through the integration of information models, which serve as the framework for the KG, identities that allow for appropriate categorization of underlying nodes, and context [IBM, nd]. Ontologies are frequently referenced to in this context as a blueprint for organizing information within a knowledge domain. It establishes the composition of data, with categories, attributes, connections, and contextual knowledge such as definitions, associations, and regulations [Union, nd]. An ontology provides a foundation for KG instances to attain data coherency and to ensure an unambiguous comprehension of the data model. Simply put, an ontology can be thought of as the data model of the KG [Oxford Semantic Technologies, nd] [Ontotext, 2023]. There is an ongoing discussion regarding the differentiation between ontologies and KGs. This discussion is motivated by the fact that both ontologies and KGs utilize nodes and edges to describe relationships between entities, commonly represented by RDF triples. Consequently, they may seem comparable, particularly when presented visually.

Kadaster has created the Kadaster Knowledge Graph (KKG), a KG customized for the Netherlands, which adheres to national and international standards for linked data as defined by World Wide Web Consortium (W3C). The KKG enables the linking of separate land registers, simplifying the process of requesting information by users, by allowing them to ask a single question with all required criteria, eliminating the need for sub-querying individual datasets. The KKG is compatible with the SPARQL query language and draws on data from open sources: the base register of addresses and buildings (BAG), the base register of large-scale topography (BGT), the base register of topography (BRT), the base land register (BRK) and public law restrictions (PB). In addition, the KKG includes a glossary with definitions for KKG-specific terminology, which can be conveniently ordered alphabetically, hierarchically or by group. This obviates the need to consult a catalog when encountering unfamiliar terms. Additionally, the KKG includes datasets, narratives, queries, and examples of a SPARQL endpoint [Kadaster, ndd]. The KG can be viewed in Figure 2.24, depicting the connections and nodes between each other. Users can refine the visualization by filtering it by relationship types, datasets and types, or by conducting a direct search. Kadaster has developed a chatbot named 'Loki' based on the KKG, which stands for Location-Based Land Registry Information. This chatbot demonstrates the capability to provide land administration information in a comprehensible language to the general public [Ronzhin et al., 2019].

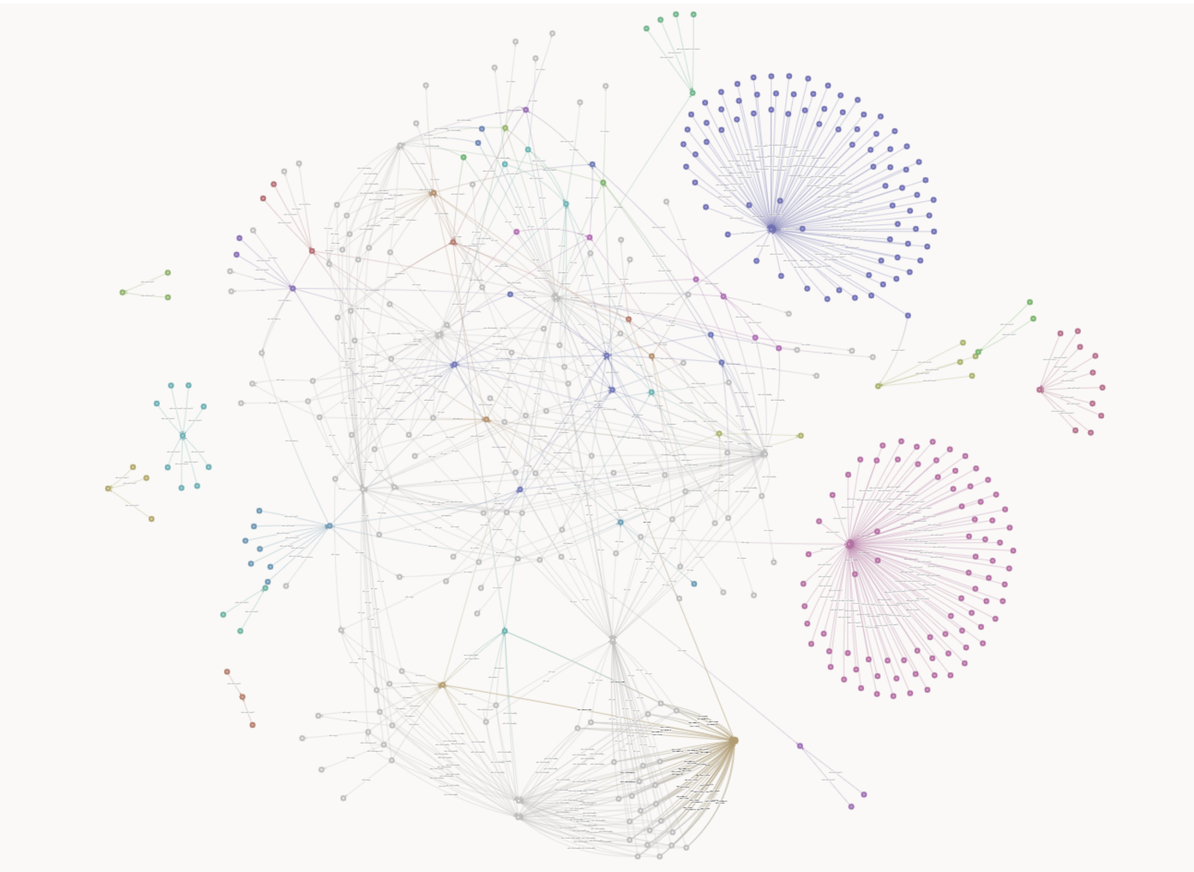


Figure 2.24: Visualization Kadaster Knowledge Graph [Rowland, nd]

2.5.1. Open land registers

The section provides details on the open land registers that are available as open data in the KKG and within the scope of this study.

Basisregistratie adressen en gebouwen (BAG) (English translation: Base register of addresses and buildings) The BAG contains information about all addresses and buildings in the Netherlands. The BAG register is made available as part of the KKG as linked data. Municipalities are source holders of the BAG, meaning they are responsible for including the data and its quality. The data is made available through the LV BAG (National Provision BAG), which is maintained by Kadaster. People with a public task are obligated to use the data from the LV BAG. The BAG consists of information on various object types and attributes. The BAG is part of the government's system of base registrations and is therefore a base register in the Netherlands [Digitale Overheid, 2022].

Basisregistratie Kadaster (BRK) (English translation: Base land register) What is part of the BRK is layed down in Art. 48 of the Cadastral law [Bartels et al., 2021]. The BRK consists of the Cadastral Register and the Cadastral Map. The BRK contains information on parcels, property, mortgages, real rights (such as leasehold, superficies and usufruct) and pipe networks. It also contains cadastral maps with parcel, parcel number, area, cadastral boundary and state, provincial and municipal boundaries. The Kadaster manages the BRK and makes the data available to various users like organizations with public tasks or institutions. The Kadaster links the BRK with the BAG, HR and BRP, so there exists a transfer of data from these registers to the BRK. The BRK is part of the government's system of base registrations and is therefore a base register in the Netherlands [Digitale Overheid, 2022].

The Netherlands has a system of registration of deeds, of which the BRK is a representation [Bartels et al., 2021]. So, it is important to realise that the system of land registration can be characterised as an incomplete registration of deeds. Incomplete meaning that rights can be acquired (and lost) without this being apparent from the registers. For example, in the case of prescription, inheritance and marriage in community of property. Also a registration of a transaction (i.e. the deed containing the transaction) in the public registers does not provide any guarantees. The BRK as a representation is the entry point to the public registers and thus acts as an index [Dutmer, 2016]. Therefore, the BRK may contain all kinds of errors, such as an incorrect link between the BRP and the BRK. It is also possible that a deed is not registered with the correct cadastral parcel in the BRK. In this case, the deed is registered but is not actually traceable. Errors are mandatory to be reported, but still no guarantees can be derived from the BRK.

Publiekrechtelijke beperkingen (PB) (English translation: Public law restrictions) Public law restrictions are part of the BRK, denoted as BRK-PB, and refer to restrictions imposed by the government that determine what a person may or may not do with a property or piece of land. In more detail, it is the restriction on the right to use or dispose of immovable property, or a right to which that property is subject, other than a private law restriction [Overheid, 2024b]. Ministries, provinces, water authorities, and municipalities are the source holders of the PB, which are subsequently registered in the public registers by Kadaster. There are 48 types of restrictions recorded, varying from specific to general, the most common being: designation as a national or municipal monument, notification for home improvement, municipal right of first refusal, expropriation order, public law anti-speculation clause (e.g. self-occupancy or prohibition of resale), and soil remediation order.

This chapter described the state of the art of the multi-part LADM and land administration in the Netherlands regarding land registration, valuation information and spatial plan information. This chapter also elaborated on the development of a country profile and the previously developed country profiles of the Netherlands. The chapter concluded with an explanation of the principles of linked data and the Kadaster Knowledge Graph. The next chapter will discuss the methodology of this research.

3. Design of prototype

This chapter describes the methodology to answer the main research question and sub-research questions previously defined in Section 1.3. First, the methodology approach of this research is described, and Sections 3.1 till 3.4 will elaborate on this by breaking the methodology down into more detailed steps. Section 3.5 elaborates on the datasets and tools used in this research.

This research will follow a methodology approach based on Design Science Research as earlier elaborated on in Section 1.5. This methodology is shown in Figure 3.1. This methodology consists of six steps which include the identification of use cases and describing the current state of the use cases (see Section 3.1 and Chapter 4), conceptual modelling of the country profile (see Section 3.2 and Chapter 5), implementation with linked data and querying (see Section 3.3 and Chapter 6), and an assessment by a comparison of the use cases (see Section 3.4 and Chapter 7). As indicated in Figure 3.1, the conceptual modelling and implementation are iterative steps, and the results of the implementation and querying steps return back and relate to previous steps in the methodology.

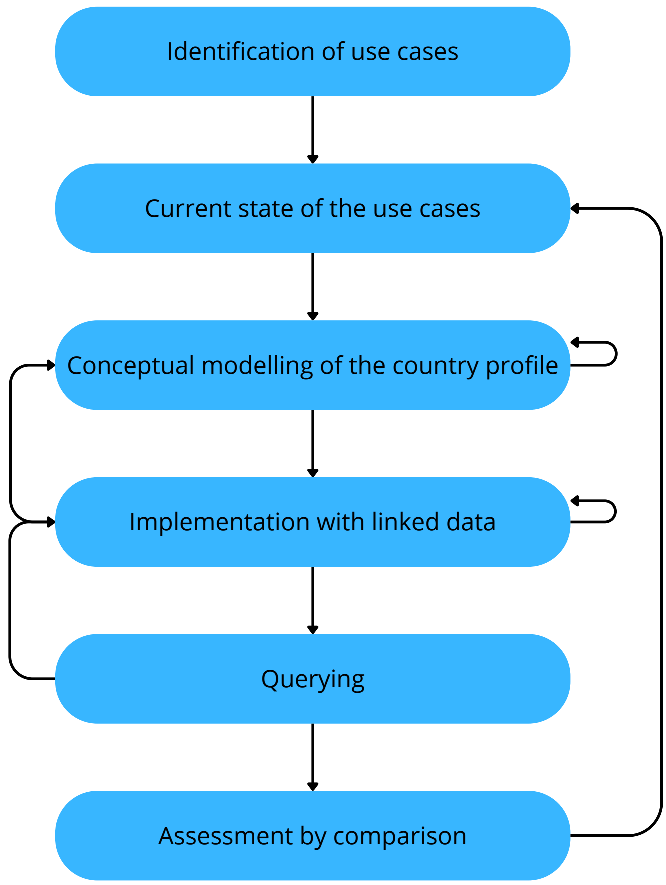


Figure 3.1: Methodology of this research

3.1. Identification and current state of use cases

Use cases are identified to assess the effects of the application and implementation of LADM in the Netherlands. This assessment is done as a last step in this research by comparing the current state of the use cases to the use cases with LADM implementation. Use cases centre on specific examples rather than one-time cross-sectional studies of many individuals. Importantly, use cases allow for generalizations to be drawn, in this case on the application and implementation of LADM in the Netherlands [Bennett et al., 2012].

Land administration data in the Netherlands is distributed among several registers and geoportals. In order to assess the effect of the application of LADM in the Dutch context, use cases are identified with the characteristic that users must collect data from multiple geoportals [Krizanovic et al., 2023]. Possible use cases that fulfil this criterion are use cases related to real estate transactions and spatial planning. The use cases focus on the retrieval of data as the scope of this study is on the data dissemination and not on the data registration.

Preparation for real estate transaction In the preparation for real estate transaction a potential real estate buyer (typically a non-professional citizen) seeks to explore his or her options before finalizing the purchase. The buyer seeks information about property rights and restrictions, spatial plans, and surrounding property values. The transfer of rightful ownership requires the involvement of a notary during the transfer process, which also involves new information to be retrieved. So, in this use case there are two different users, first a citizen (non-professional) and when the transfer will take place the notary (a professional). Several different situations can arise during a real estate transaction. For example, in more complicated scenarios, a homeowner's death may create additional challenges. As a result, real estate transactions can be classified as either simple or complex.

Preparation when applying for a building permit When applying for a building permit in the context of existing spatial plan(s), one needs to interact with the municipality and may encounter land use limitations. Currently, it is known that applicants do not receive a comprehensive information file when submitting their application. The implementation of LADM may demonstrate that it is possible to overlay data from multiple registers so a comprehensive file of limitations will be known.

Process models are considered to provide a better understanding of processes, enabling improved communication between stakeholders, to optimise current procedures and/or process elements and, to predict the impact of changes in dissemination strategies, such as the introduction of new technologies [Krizanovic et al., 2023]. The current state of the identified use cases will be modelled as a process model with actors, activities and resources. Additionally process components can subsequently be matched with the LADM classes which can be used to denote identified process components. Clarifying the authority and responsibility for each activity and identifying the necessary resources to be accessed [Zevenbergen and Stubkjaer, 2005].

3.2. Conceptual modelling of the country profile

The second edition of the LADM has yet to be officially published. To map the second edition of the model, information available must be utilized. This process requires mapping all classes and attributes per part, which establishes the foundation for the next phase of creating the country profile for the Netherlands. Several studies propose a methodology for creating a country profile. A proposed methodology by will be used as a guideline to develop the country profile of the Netherlands, as was earlier elaborated on in Section 2.3.

3.3. Implementation with linked data and querying

Implementing the conceptual model aims to create a prototype that can demonstrate the application of the LADM-based approach through querying of the use cases. This implementation will utilize a linked data strategy that employs ETL (Extraction, Transformation, and Load). First, data will be extracted from a source, and then transformed into datasets conform the conceptual model, and finally loaded into a new LADM compliant database, based on the ontology resulting from the conceptual model. The implementation of the conceptual model will be supported by a system architecture, see Chapter 6.

The development of the country profile of the Netherlands results in an UML model, which serves as the basis of the ontology in the implementation. The objective is to convert this UML model into a linked data model. This is feasible by transforming the data to RDF triples at both the instance and schema level. Instance level refers to individual records or data points within a dataset or database. Schema level deals with the broader perspective of data, considering the entire dataset. At the instance level, relationships in the UML model are transformed into RDF language, i.e. triples that describe the model (relationships between object types are identified). At the schema level, RDF language is utilized for the data itself. This means that the relationships between object types are applied to the values of the data.

As an example, the ontology shows that 'Verblijfsobject' in BAG and 'Addressable Object' in WOZ are equal to 'LA_LegalSpaceBuildingUnit' in LADM. To achieve this equivalence, BAG and WOZ data must be transformed into the ontology using RDF at both the instance and data level. Then, a URI is utilized to indicate that 'Verblijfsobject' in BAG is equal to 'Addressable object' in WOZ. In this way, the URI establishes a path that links these two entities. Following, the SPARQL language can be utilized for querying data. The methodology of implementing LADM consists of the following steps:

1. Develop an ontology.
2. Extract the data.
3. Transform the data conform the ontology with RDF triples.
4. Design URIs.
5. Load the data into a linked data database.
6. Query with SPARQL to retrieve information.

3.4. Assessment by comparison of the use cases

The purpose of the querying process is to assess the implementation of LADM for data dissemination with a linked data approach, examining its benefits and drawbacks. To evaluate the use cases, a benchmarking approach will be utilized, identifying various metrics (e.g. ease of use or quality) to assess the performance of the prototype compared to the current situation (the benchmark) [Gurumurthy and Kodali, 2008]. The assessment of the current state of the use cases will be based on literature, communication with experts in the field and own experiences. The assessment of the state of the use cases with the implementation of LADM will be based on communication with experts, a usability test, and own experiences.

3.5. Datasets and tools

Registers The registers that will be utilized in this study are: the base register of addresses and buildings (BAG), the base land register (BRK), the public law restrictions (PB), and spatial plans. These registers have been previously explained in Sections 2.5.1, and 2.2.3. As spatial plan data is only available as linked data for the municipality of 'Zeewolde', the scope of this study is spatially limited to this municipality. Data from the base register of persons (BRP) is included using fake data, as official data cannot be used publicly due to privacy laws. Also, fake data was utilized for the WOZ data as Kadaster is not the owner of the data, so no official data could be included.

UML Modelling There are various tools available for creating a UML model. Drawio is used for UML modelling, this choice is the result of financial considerations and personal preference and the ease of use.

Linked data implementation There are various tools available for deployment that offer many options and choices during implementation with linked data. Before implementation, familiarization with linked data will be done using the book Learning SPARQL [DuCharme, 2011]. For the development of the ontology, Protégé will be utilized. The SPARQL queries are written in Kadaster's Triple Store web environment.

This chapter described the methodology used to design the prototype. The methodology is based on DSR and consists of six steps, including the identification of use cases and the modelling of the current state of the use cases, the conceptual modelling of the country profile, the implementation of the country profile with linked data and queries. The methodology concludes with an assessment by comparison and evaluation of the use cases. The next chapter discusses the results of this research methodology.

4. Use cases

Two use cases are identified to assess the impact of the application and implementation of LADM for data dissemination in the Netherlands. The identified use cases pertain to real estate transactions and applications of a building permit. The following sections provide a detailed elaboration on the current state of these use cases and their respective processes. Section 4.1 will elaborate on the use case of real estate transaction and Section 4.2 will elaborate on the use case of a building permit.

4.1. Real estate transaction

Analysing the preliminary phase: information sources in residential real estate exploration. This phase involves obtaining and gathering information. Before committing to a real estate purchase, individuals seeking to buy property investigate their options. This typically involves examining different properties of real estate, including their intended use, construction year, and surface area. Additionally, potential buyers may be interested in the value of properties within their local area, particularly if they are looking within a specific budget. Such information can be sourced from the BAG and WOZ. The WOZ value provides relevant information about the value of real estate and can be accessed through the Wozwaardeloket geoportal. Additionally, individuals may be interested in the overall size of the parcel and the (limited) rights to the property. The BRK and BRK-PB should be consulted for details on these properties. Note that the BRK solely serves as an access portal for accessing the souce documents in the public registers, and does not offer any legal guarantees.

The process model of this phase in real estate transaction is visualized in Figure 4.1. It is assumed that nor the (potential) buyer nor the seller are assisted by an expert, in particular a real estate agent, in this phase. The green circle indicates a start event, representing the point at which a process instance starts. The red circle indicates an end event, representing the point where the process is considered to be completed. The rectangles with round edges correspond to process steps, and the horizontal dotted lines indicate registers to be consulted during this step.

In this phase, it is assumed that potential property purchasers are likely to be interested in obtaining answers to the following questions:

- What is the purpose of use of the real estate?
- What are the current property valuations of the real estate and real estate in the area?
- When was the property constructed?
- What is the surface area of the property and its parcel?
- Are there any restrictions or limitations on the property?

Currently, there are at least four registers that need to be consulted to answer these questions. Namely, the base register of addresses and buildings (BAG), the base land register (BRK), public law restrictions (BRK-PB) and the Wozwaardeloket geoportal.

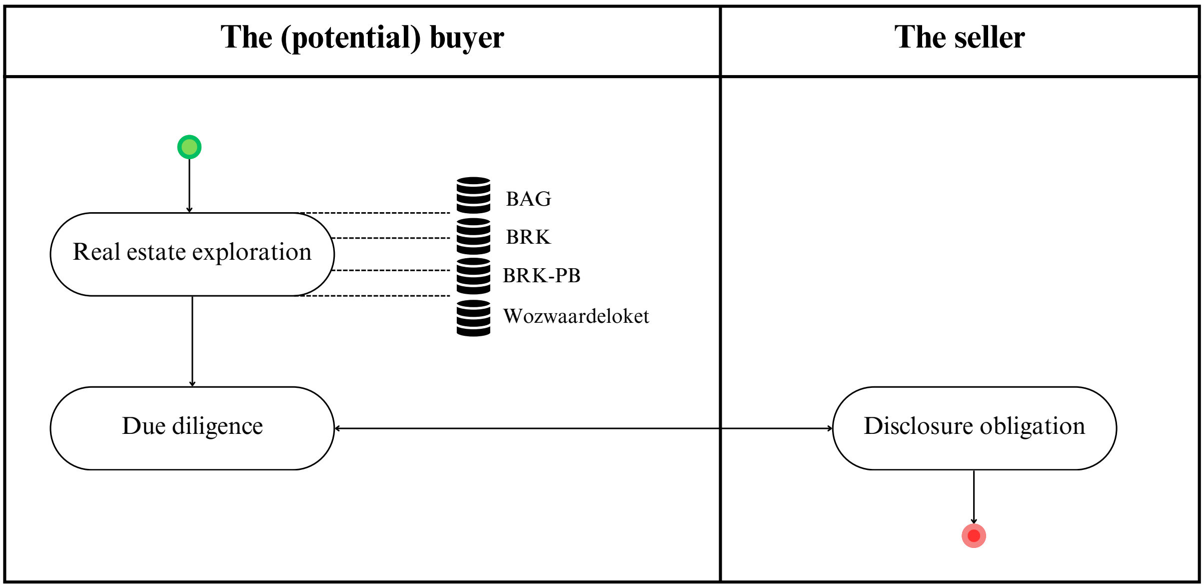


Figure 4.1: Process model real estate transaction - Preliminary phase

Analysing the sequential phase: sale and transfer of the real estate. In this phase it is necessary to understand that lawfully there are two types of persons: a natural person and a juridical person. A natural person is a human being with rights and obligations who can close agreements and own property. Juridical persons are companies and organisations (e.g. a foundation, association, cooperative etc.) that have a legal structure with legal personality. If a company is a juridical person, it has legal capacity meaning that the company has rights and obligations, can make decisions, and can enter into agreements and own property, just like natural persons [Kvk, 2023]. It is assumed that neither the buyer nor the seller uses the support of a professional, specifically a broker (real estate agent) in this phase. The analysis of the transactional process in real estate transactions will be limited to a standard case, detaching from all possible complexities.

After the seller and the buyer have come to an agreement, and the purchase agreement has been concluded, the next step is the transfer of legal ownership. This requires in the Dutch law the involvement of a public notary. During the process of real estate transaction, the notary retrieves information regarding the buyer, the seller and the real estate. The sale and transfer of real estate is modelled as a process model to understand what steps are taken, by whom, and what resources are consulted, see Figure 4.2. The first step involves the preparation of the contract of sale and signing of the contract of sale agreement by the seller and the buyer, after which it is handed to and received by the notary.

The responsibility of the notary is to conduct a cadastral search and verify any mutations in the legal status of a registered property. Additionally, the notary ensures that the transaction is correctly registered and that no changes have occurred in the meantime, in particular an establishment of a mortgage, a seizure on the immovable property or bankruptcy of the seller [Bartels et al., 2021] [KNB, 2011]. This is done by the notary in three different phases.

In the first phase the notary makes up the, so called, 'zero situation' or 'pre-screening', this means that the situation regarding the parties and the real estate is made up as it is at that moment. Multiple checks are carried out to establish whether a person is bankrupt, under receivership, if the real estate owner is still alive, if the person's identity is valid, and personal details relating to civil status and residential address. These checks involve the consultancy of several registers as indicated in the process model. Personal details such as name and residential address are stored in different registers, depending on whether the person is a natural or legal person. For natural persons, the appropriate registry to consult is the base register of persons (BRP), whereas for juridical persons, the commercial register (HR) should be consulted. During the pre-screening, the information obtained from the BRK may not be sufficient. Therefore, it is always necessary to consult entries in the public registers directly.

Subsequently, a second round of checks will take place making up for the, so called, 'first situation' or 're-screening'. This takes place shortly before the deed will be signed. If all requirements are met again, the notarial deed will be signed by the buyer, the seller, and the notary. The registrar at Kadaster examines copies of the signed notarial deed to determine compliance with registration requirements as specified in Art. 18 of the Cadastral Act [Overheid, 2023]. If everything is okay, the registration is accepted in the public register, the notarial deed is registered in the public register and the documents in the BRK are updated accordingly.

Following, the notary executes a third round of verification to address the, so called, 'second situation' or 'post-screening'. The post-screening is done to verify the success of the transaction, that is, whether the registered property has been acquired by the buyer without any interim seizures or mortgages. When everything is okay, the purchase price is made available and paid, and the buyer and seller are notified about the transfer of real estate. Information on the process of a real estate transaction was obtained from literature and expert consultation [Bartels et al., 2021].

In this phase of the real estate transaction, the notary must address the following questions:

- Is the person bankrupt?
- Is the person under receivership?
- What is the identity of the person?
- Is the person alive (in case of a natural person)?
- Are the persons's name, address details, and civil status correct and complete?
- Are there any mortgages or other rights and restrictions, including public law restrictions, on the property?

Currently, there are six registers that need to be consulted to answer these questions. Namely, the bankruptcy register, the guardianship and administration register, the identity verification register (VIS), the base register of persons (BRP) or the commercial register (HR), the base land register (BRK) and the public registers.

The costs incurred from conducting the researches during the transactional process are charged to both the buyer and seller, thereby creating transaction costs. Minimising transaction costs is a paramount public interest, since lower costs facilitate increased transactions thus helping to power the economy [Koninklijke Notariële Beroepsorganisatie, 2023]. Pre-screening, re-screening, and post-screening each take an average of 11, 8, and 8 minutes, respectively [Koninklijke Notariële Beroepsorganisatie, 2023]. The mean duration for a single search, rounded up, is nine minutes. When accounting for the average gross salary, this results in pre-screening costs averaging to 15.59 euros for a notary's office. The costs of re-screening and post-screening are both 11.41 euros, resulting in a total cost of 38.41 euros for the office supervising the transaction.

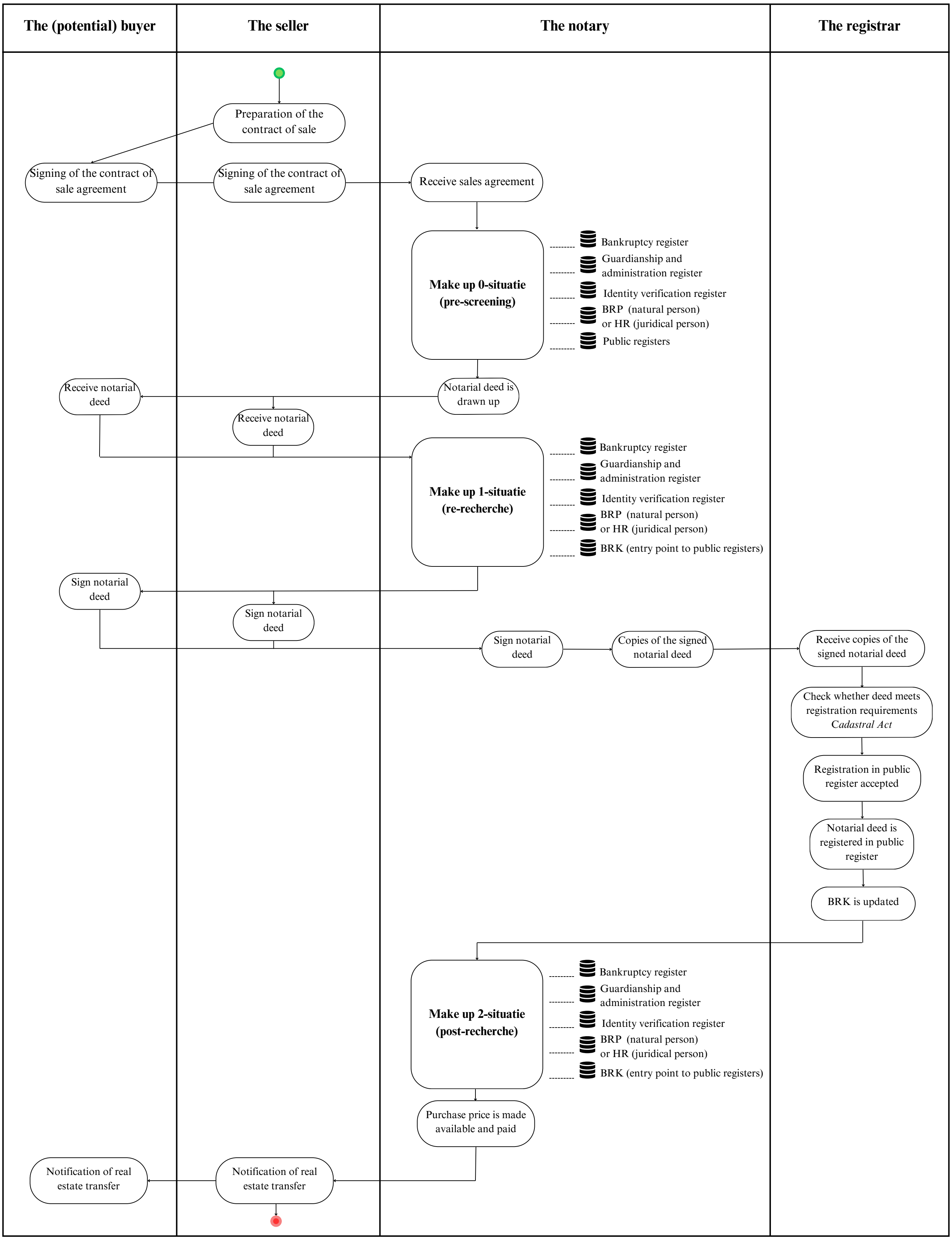


Figure 4.2: Process model real estate transaction - Sequential phase

4.2. Building permit

Analysing the preliminary phase: information sources in preparation of a building plan and the application for a building permit. Individuals, developers, contractors or any other interested party looking to construct, renovate, or expand upon an existing building need to comply with the Environment and Planning act and may require a building permit. The new Environmental and Planning Act came into force on 1 January 2024 resulting in Omgevingsloket being the new central online web environment for spatial plans and permit applications, previously being Ruimtelijkplannen. Thus for this use case the new Environmental and Planning act is considered. A clear description of the construction project, including drawings and plans, is initially required during application for a building permit. This can range from simple renovations to large-scale new construction. Before applying for a building permit, it is essential to check whether the proposed building plan complies with the applicable spatial plan. To access the municipality's spatial plans, individuals need to consult the online environment of Omgevingsloket regels-op-de-kaart (rules on the map). Omgevingsloket acts as a point of reference for both applicants and municipal officials to comprehend and verify relevant public law limitations.

When preparing a building plan, it is advisable to check first whether a permit is required, which can also be done at Omgevingsloket. If it appears that a permit is required, it will be necessary to verify whether the building plan is in compliance with the spatial plan(s) of the municipality. It is necessary to comply with the rules laid down in spatial plans regarding building regulations and other planning legislation. One may choose to obtain this information on spatial plans before the building plan is drawn up, so that it can be taken into account beforehand.

Someone who is preparing a building plan is likely to ask themselves the following questions:

- What spatial plan(s) are attached to a specific address a building plan is developed for?
- What rules are laid down in the spatial plan regarding building regulations and planning regulation?
- Do I need to carry out any research regarding environmental impact of my plan?

In this phase there is one register to be consulted in preparation of a building plan and the application for a building permit. Namely, spatial plans, which information can be consulted on the web environment of Omgevingswet. Figure 4.3 shows the process model for this phase, in which a building plan is prepared and preparations are made for applying for a building permit.

Analysing the sequential phase: application for a building permit. When submitting a building permit application, a person must state how the plan is in compliance with the public law framework and regulations. During the assessment of the application, the municipality examines the public law aspects, including compliance with spatial plan(s) and other spatial regulations. This requires consultation of the public law restrictions and spatial plans. Omgevingsloket offers clear insights into spatial plans and regulations, essential for securing a building permit that conforms to public law restrictions. In addition to these checks, personal information and cadastral data will also be verified. Figure 4.4 shows the process model of this phase, during the application assessment.

Before granting a building permit, the municipality checks the building plan according to the following questions:

- Is the personal information on the application in line with the information in the base register of persons/commercial register?
- What is the cadastral data regarding the address of the proposed building plan?
- What spatial plans are applicable to the address of the proposed building plan?
- Is the proposed building plan in line with the designed spatial plans?
- What public law restrictions are applicable to the address of the proposed building plan?
- Is the proposed building plan in line with the public law restrictions?

Based on this assessment, the municipality makes a decision to either grant the building permit if the plan is in compliance with the rules and regulations or to deny it if there are significant legal or regulatory issues. Before granting a building permit, three registers must be consulted during the assessment of the building permit application. These are the base register of persons (BRP) or commercial register (HR), public law restrictions (BRK-PB) and Omgevingsloket for spatial plans.

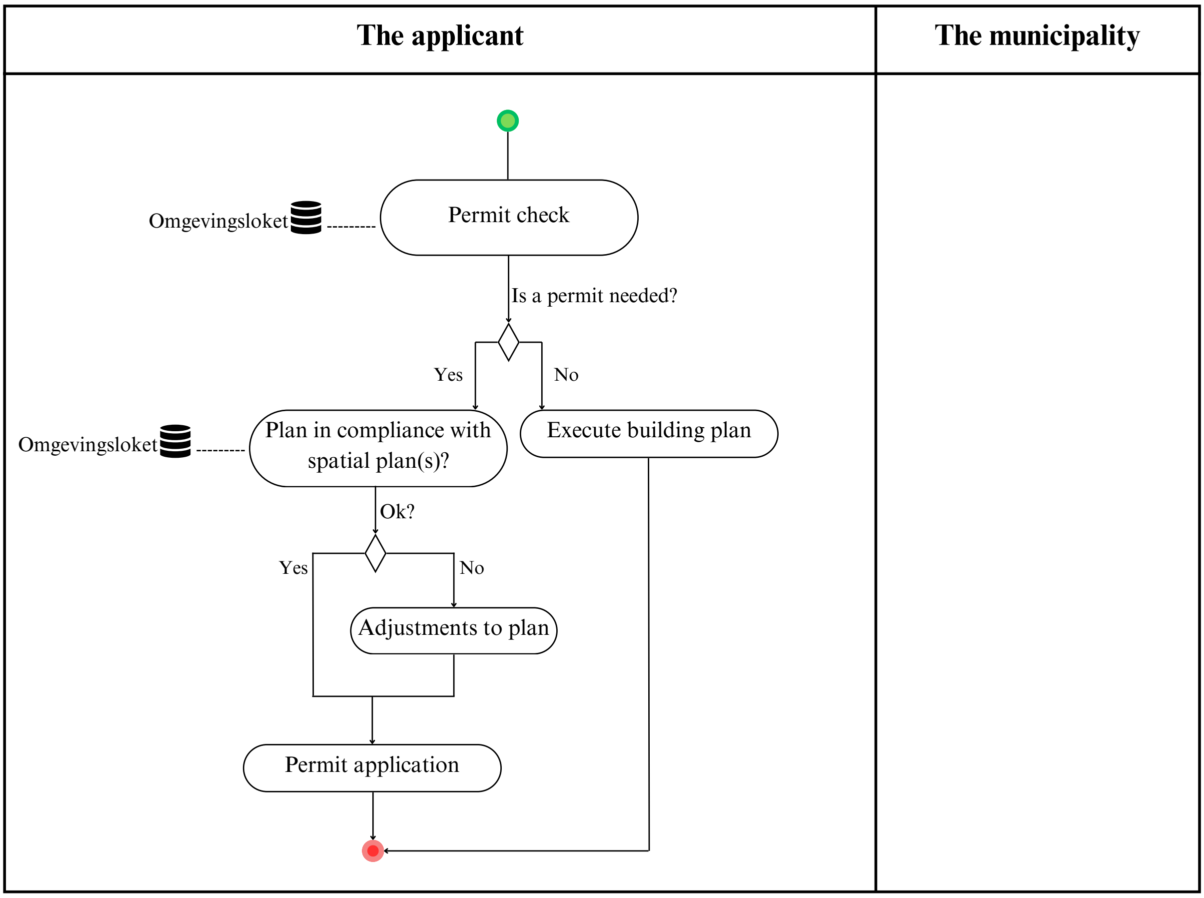


Figure 4.3: Process model applying for a building permit - Preliminary phase

The process models of the selected use cases showed that multiple registers are to be consulted for both the real estate transaction and the building permit application. The following chapter discusses the development of the country profile of the Netherlands.

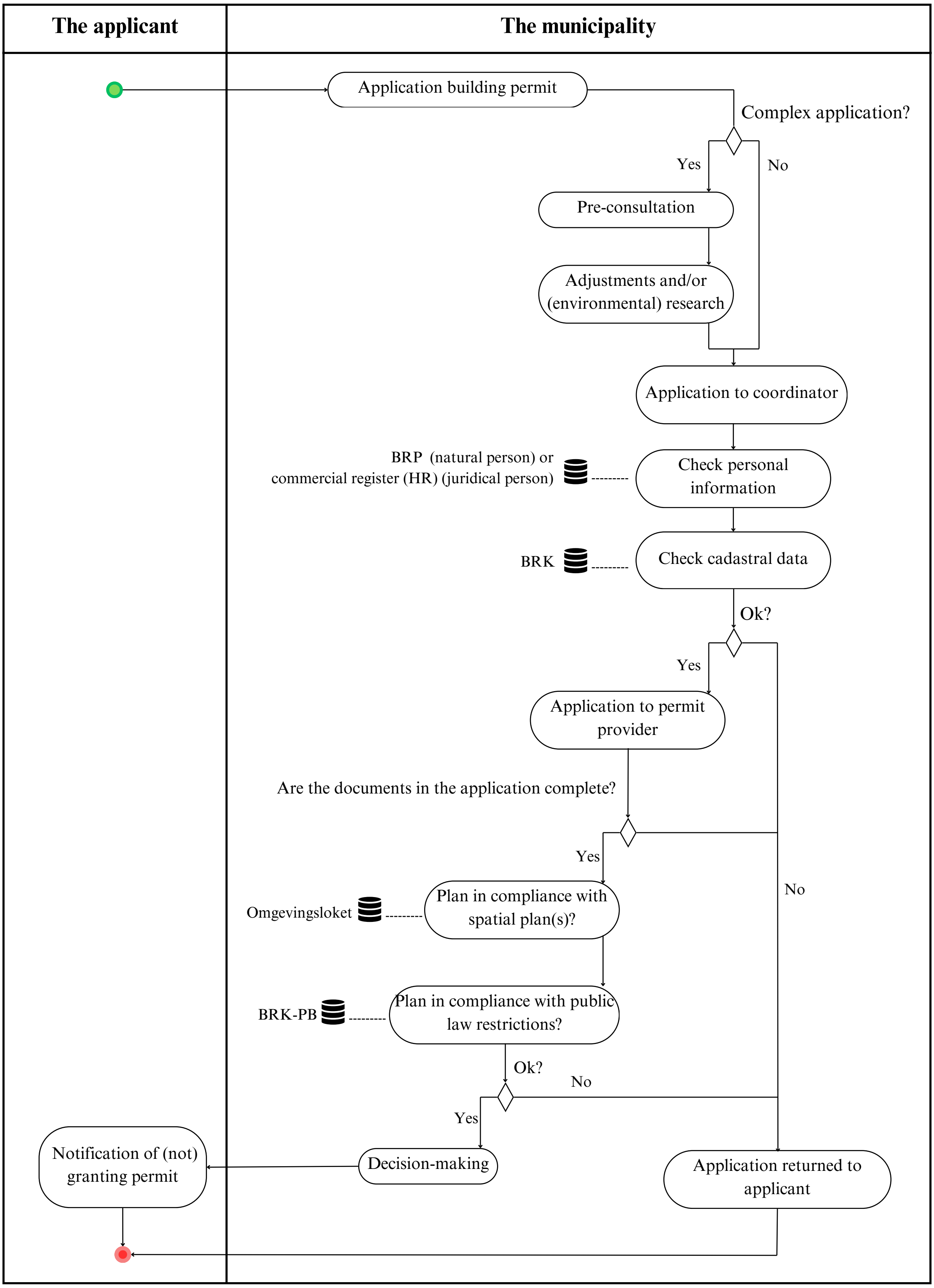


Figure 4.4: Process model applying for a building permit - Sequential phase

5. Country profile of the Netherlands

This chapter discusses the development of the country profile of the Netherlands. First, the development of the country profile for core LADM is discussed in Section 5.1. The development of the country profile for valuation information is discussed in Section 5.2. Lastly, the development of the country profile for spatial plan information is described in Section 5.3.

The official documentation of Part 1 - Generic conceptual model states the requirement that "Any country profile established using the elements defined in conformance with ISO 19152:2012 shall remain conformant with this version of the standard" [ISO, 2023]. This means that any country profile developed using the elements from ISO 19152 must continue to comply with the specifications and guidelines set forth in the standard.

LADM allows user-defined elements to be added or removed for country-specific needs. To determine the applicable elements of LADM in the Netherlands, it is necessary to map the current state of land administration systems in the country. This was limited to the scope of this study, comprising: the BAG, the BRK, public law restrictions, the WOZ and spatial plans, see Section 2.2. Three country profiles are developed, which will be linked together to form one model during implementation, see Chapter 6. The country profiles deal with the generic conceptual model and land registration (core LADM), valuation information (Part 4), and spatial plan information (Part 5). The latter two are based upon core LADM, as shown in Figure 5.1.

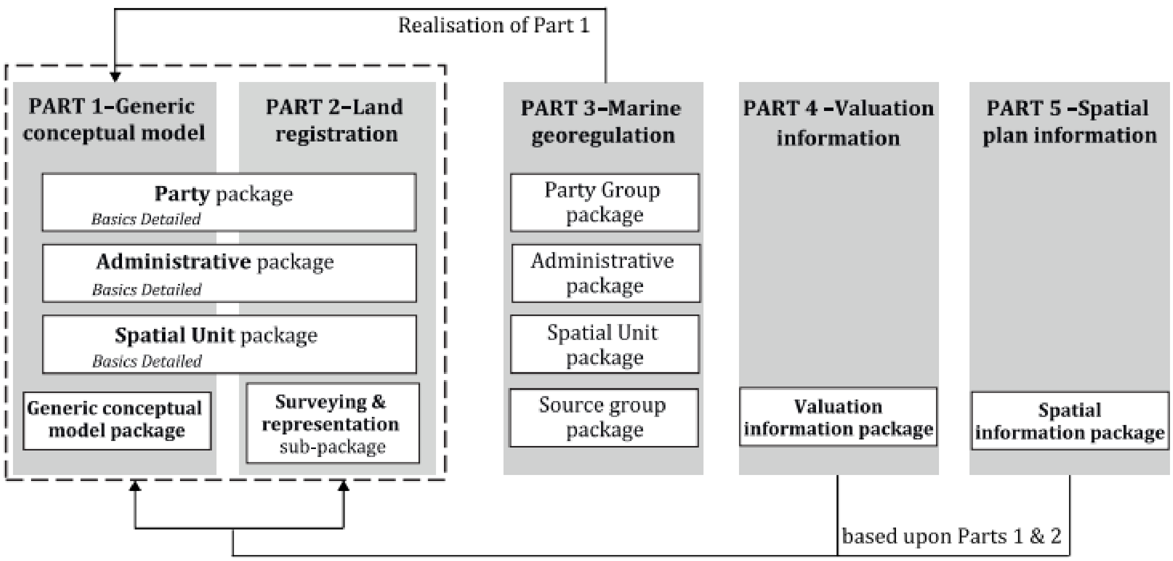


Figure 5.1: Core LADM and extended LADM [ISO, 2023]

5.1. Core LADM

Core LADM consists of Part 1 - Generic conceptual model and Part 2 - Land registration. A country profile of land registration allows the collection of data of the parties involved in the land registry, cadastral objects, property objects and legal aspects. To design a comprehensive model, it is necessary to provide an overview of the land registration system and practices in the Netherlands, as was done in Section 2.2.1. As earlier mentioned in Section 2.3.1, a country profile of the Netherlands was previously established based on the first edition of LADM [ISO, 2012]. This country profile was used as a starting point for the creation of the country profile for core LADM of the Netherlands, given the limited time span of this study and the fact that no major changes have occurred in the Dutch land registration system since the publication of the this country profile.

Country profile of the Netherlands for core LADM As mentioned earlier, given the limited time span of this study and the fact that there have been no major changes in the Dutch land registration system since the publication of the first edition of LADM, the previously established country profile of the Netherlands is used as a starting point for the creation of the country profile of core LADM. Based on this foundation, the classes are reviewed to evaluate their relevance to the current situation in the Netherlands. Developments in Part 1 - Generic conceptual model [ISO, 2023] and Part 2 - Land registration [ISO/TC 19112-2, 2023] over the last years are evaluated, and adjustments are made accordingly to the country profile as will be described in more detail below. The resulting country profile can be seen in Figure 5.2, respectively with their classes and attribute shown in Figure 5.3.

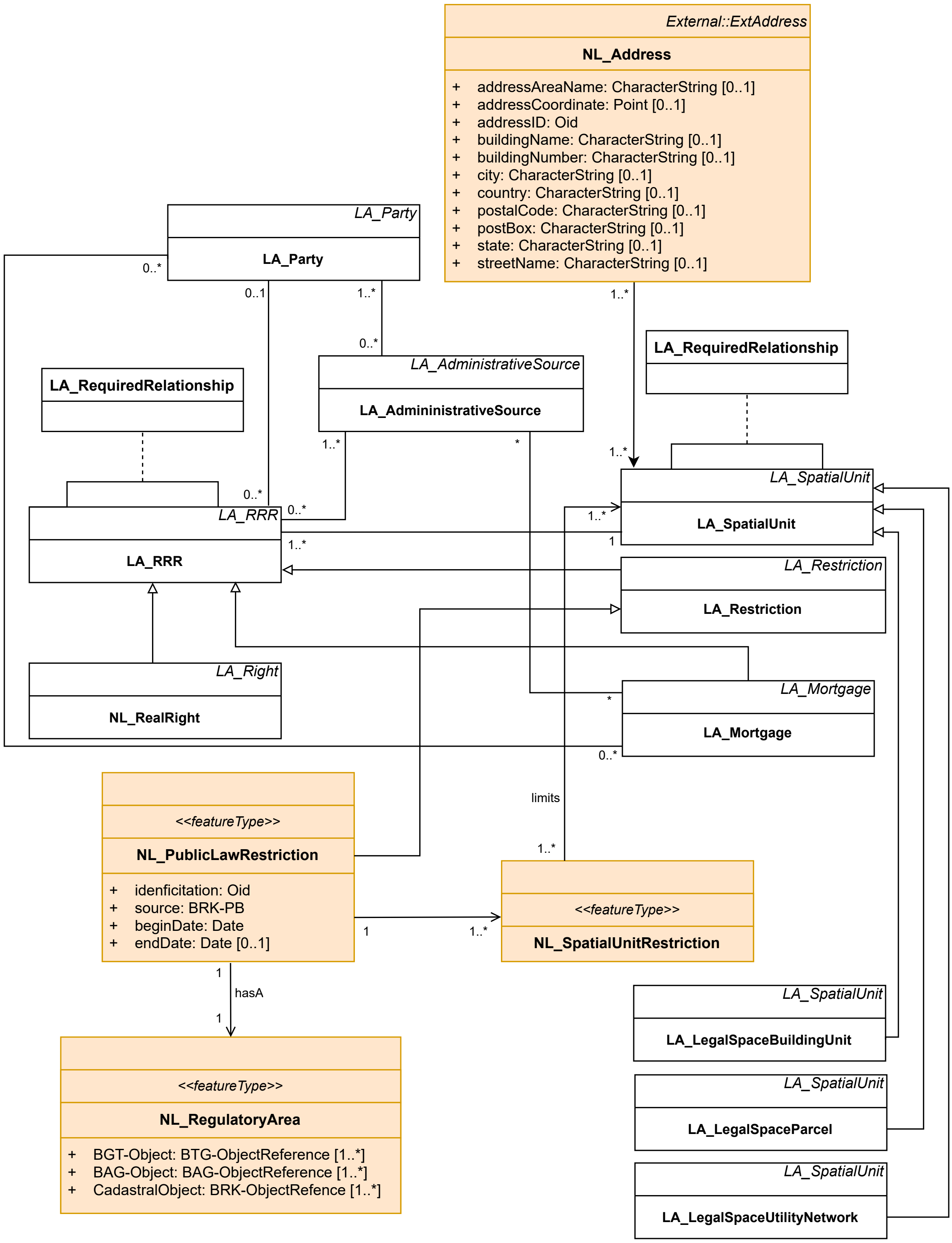


Figure 5.2: Country profile of the Netherlands for core LADM

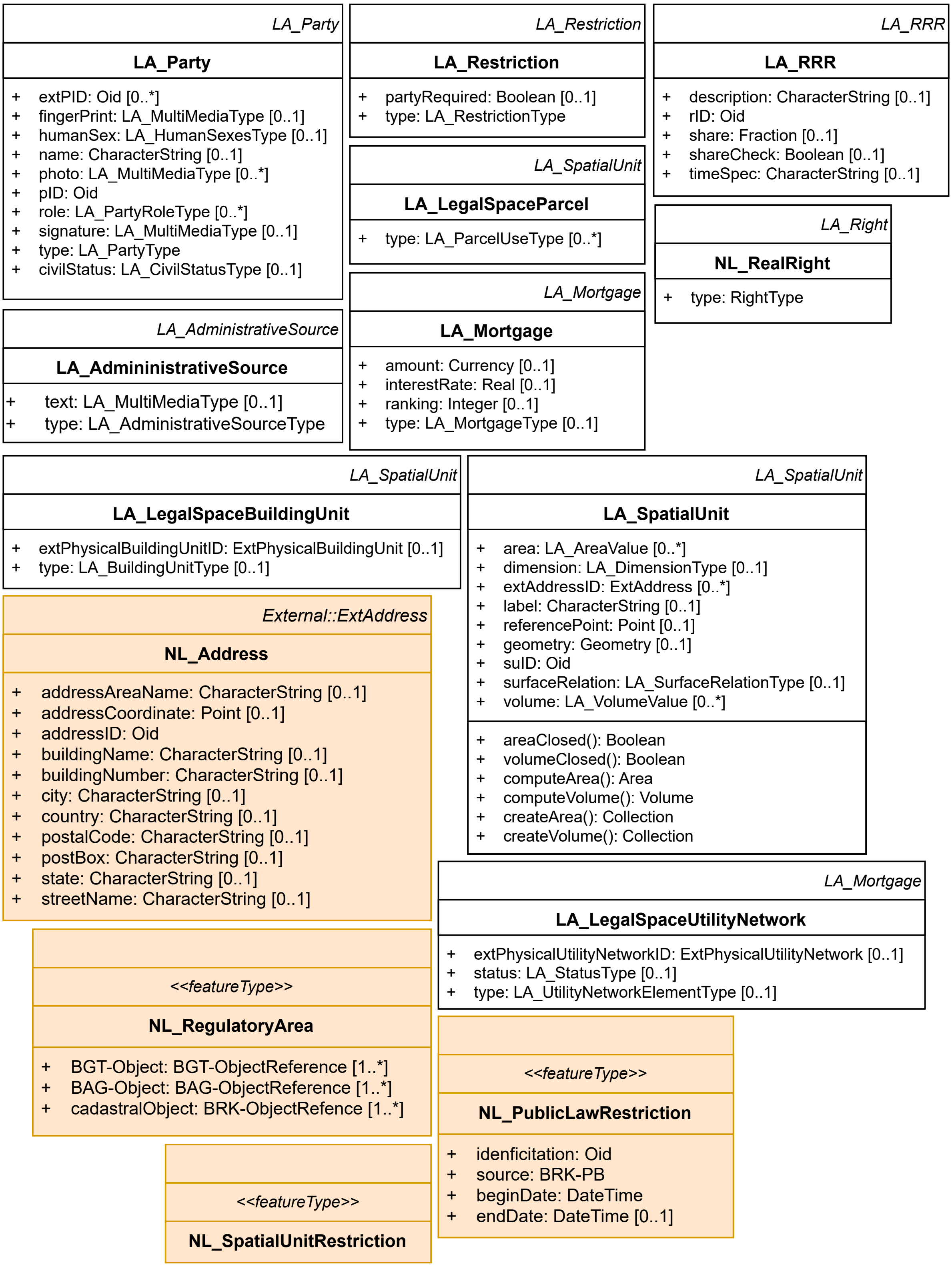


Figure 5.3: Classes and attributes of the country profile of the Netherlands for core LADM

A required relationship is added to LA_RRR as a result of developments from the first version of the LADM model. Part 1 - Generic conceptual model determines that there is a required relationship on RRR that was not present in the first edition of LADM [ISO, 2012]. Consultation with experts at Kadaster confirmed this required relationship.

It was decided to model the class LA_Mortgage as a subclass of LA_RRR. The restriction of a mortgage states that a party (usually a bank) may sell a registered property if the owner can no longer repay the loan underlying the right of mortgage. It can therefore be seen as the right to have a mortgage or the restriction that a party may sell your property. During the expert consultation it became clear that the debate about whether a mortgage is a right or a restriction has been going on for years. It is thus possible to model NL_Mortgage in several ways. Since the Kadaster Act does not make the distinction between a right and restriction [Overheid, 2024a], it has been decided to model LA_Mortgage as a subclass of NL_RRR, and not as a subclass of NL_Restriction (as is done in Part 2 - Land registrion) or as a subclass of NL_RealRight (as is done in the Dutch country profile from 2012, see Figure 2.21).

A change has been made to the class LA_BAUnit, the class has merged with the spatial unit class, LA_SpatialUnit. During the expert consultation, it was discussed that there are no basic administrative units registered in the Netherlands. This was confirmed by experts from the Kadaster. As basic administrative units are non existent in the registration systems of the Netherlands, it is essentially the same as a spatial unit. The decision has therefore been made to merge the two classes into one, for simplification. The merging of the classes LA_BAUnit and LA_SpatialUnit results in the one class LA_SpatialUnit. In the future, however, it may well be necessary to distinguish between these classes when the country specific needs of the Netherlands account for this, for example in the case of apartments with parking lots and storage rooms.

The country profile of core LADM is extended with an external class to cover country-specific information in land registration and the scope of this research. The prefix 'NL_' is used to denote this country specific class. The NL_Address class is introduced as an external class from the annex External Classes of Part 2 - Land registration [ISO/TC 19112-2, 2023]. The construction of external databases, including address data, is outside the scope of LADM. However, LADM does provide stereotype classes for these records, which indicate which record elements the LADM expects from these external sources, where available. Based on the proposed external address class, the NL_Address class is added to the country profile. NL_Address has a relationship with LA_SpatialUnit, and the relationship is 1 to multiple as one spatial unit can have multiple addresses [Kadaster, 2018].

The Kadaster has developed a UML model that incorporates a public law constraint class, as illustrated in Figure 5.4. The model reveals relationships that are utilized in the country profile. Public law restrictions are a specific kind of restriction, and in the Netherlands public law restrictions are included within expected land use. To indicate the public law restrictions as a special case of a restriction a new class called NL_PublicLawRestriction has been added as a subclass of LA_Restriction. The attribute list of NL_PublicLawRestriction contains the types of restrictions that occur in the Netherlands, identified by an Id, a start time, and an end time.

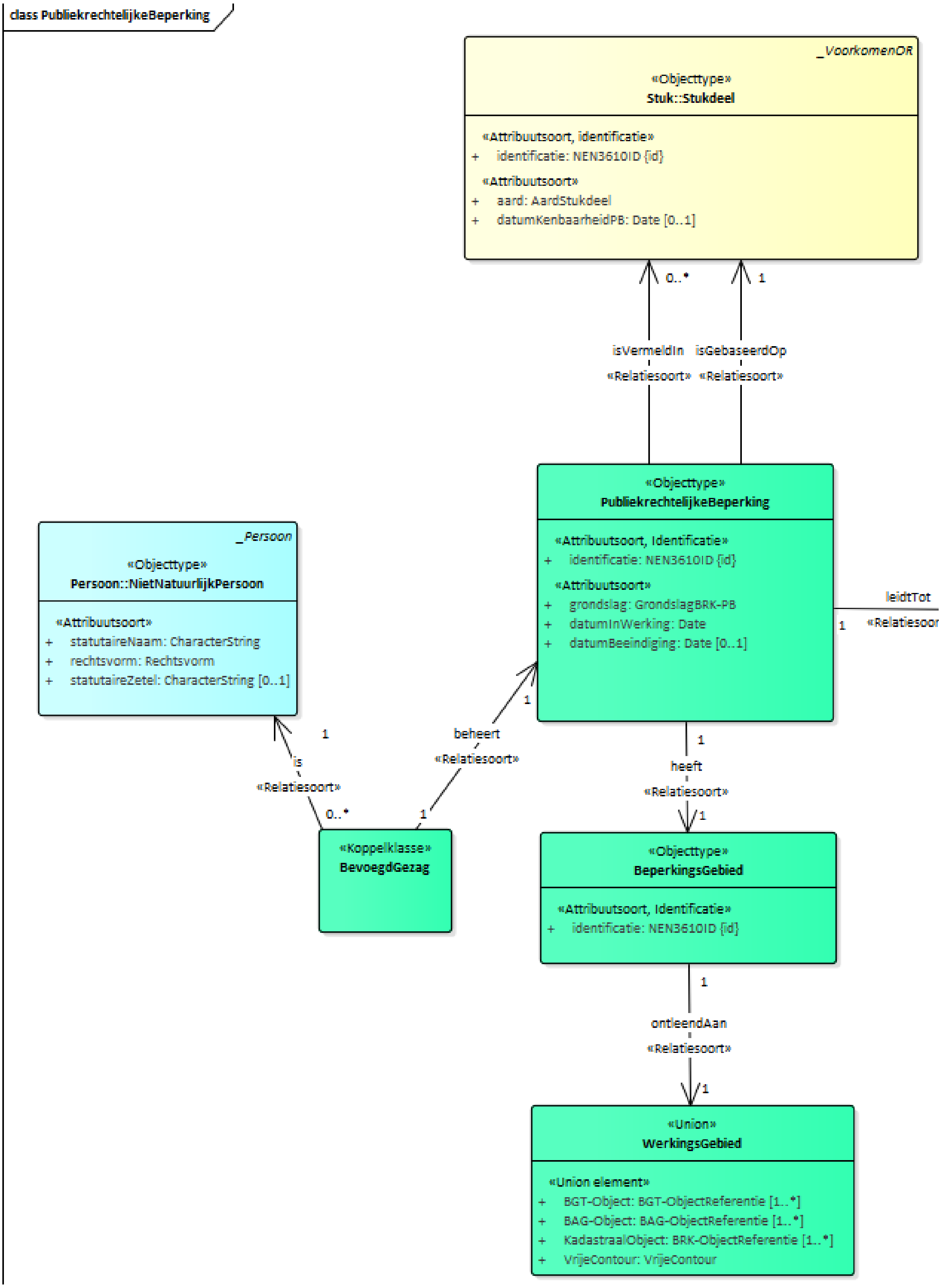


Figure 5.4: Class PubliekrechtelijkeBeperking - UML model [Kadaster, 2020]

The class NL_SpatialUnitRestriction has been added to the country profile to indicate the result of a public law restriction placed on a spatial unit. This relationship between NL_SpatialUnitRestriction and LA_SpatialUnit has been added based on Figure 5.4, defining a restriction on a spatial unit resulting from a public law restriction.

Finally, the class NL_RegulatoryArea has been added, which indicates the area of application of the public law restriction. This area is defined by objects from the BGT, BAG and BRK (cadastral object). This class indicates the area within which the public law restriction applies.

5.2. Valuation information

Part 4 of LADM comprises the valuation information of a country. The country profile on valuation information allows for the recording of data on valuation practices, including the property objects that are subject to valuation and their geometric, legal, physical, economic, and environmental characteristics. To design a comprehensive model, it is necessary to establish an overview of the property valuation systems and practices in the Netherlands, as is earlier done in Section 2.2.2. Efforts have been made already to develop a country profile for valuation information in the Netherlands [Kara et al., 2019], see Figure 2.22. The country profile for valuation information developed in previous research is used as a starting point given the limited time span of this study and the fact that no major changes have occurred in the Dutch system of valuation since the publication of this research [Kara et al., 2019].

Country profile of the Netherlands for valuation information The valuation information model is extended with new classes, characteristics and relationships to cover country specific information in property valuation. The prefix 'NL_' is used for newly added classes for the development of the country profile. Note that the basis valuation information model is taken from the overview document of Part 4 - Valuation information [ISO/TC 19112-4, 2023], and additional NL classes are taken from previous research on the country profile of the Netherlands for valuation information [Kara et al., 2019]. The resulting country profile of the Netherlands in terms of valuation information is visualized as a UML model.

The resulting country profile regarding valuation information has some changes compared to the country profile developed in previous research [Kara et al., 2019]. This is the result of developments in Part 4 - Valuation information over the last years. These changes include the removal of the two relationship on itself on the class LA_SpatialUnit, the removal of the relationship on itself on the class LA_SpatialUnitGroup, the addition of a relationship between the classes LA_SpatialUnitGroup and LA_SpatialUnit, and the addition of class VM_Valuationsource and its relationships with VM_ValuationUnit, VM_Transactionprice, VM_Valuation and LA_Party. These changes are incorporated in the resulting country profile, which can be seen in Figure 5.5. Further changes to the country profile are described below.

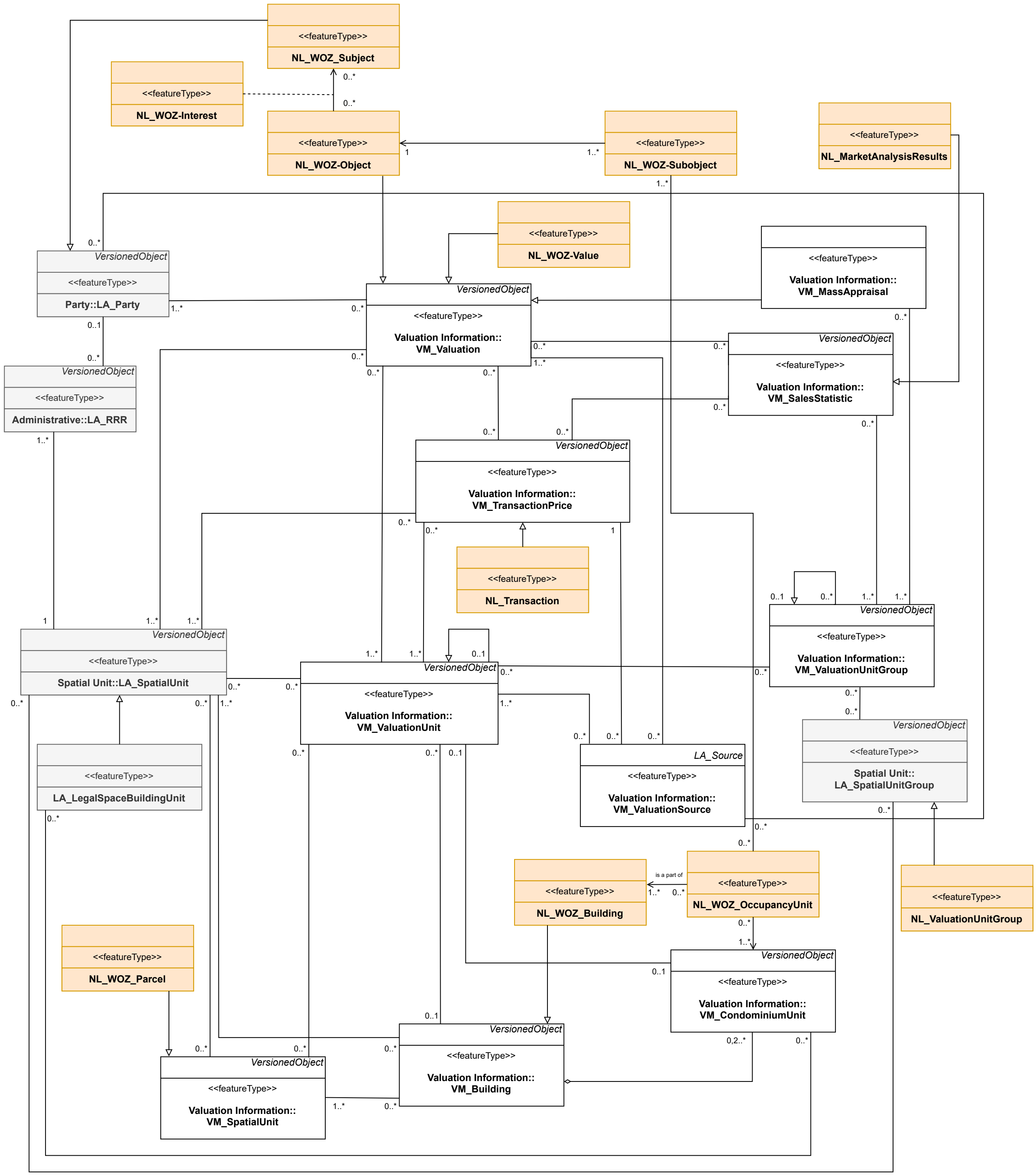


Figure 5.5: Country profile of the Netherlands for valuation information

The WOZ database contains several classes, including WOZ-value, WOZ-object, WOZ-subobject, and other WOZ-interest classes. These classes are related to classes in other registers, such as buildings in the BAG, transaction prices in the BRK, and people and companies as parties in the BRP and HR. To represent the other object characteristics used in property valuation, some super classes were created. These classes include NL_WOZ_Building, NL_WOZ_OccupancyUnit, NL_WOZ_Parcel, and NL_WOZ_Subject.

The attributes of the country specific classes are shown in Figure 5.6, together with the attributes of the general classes that are shown in Figure 5.7.

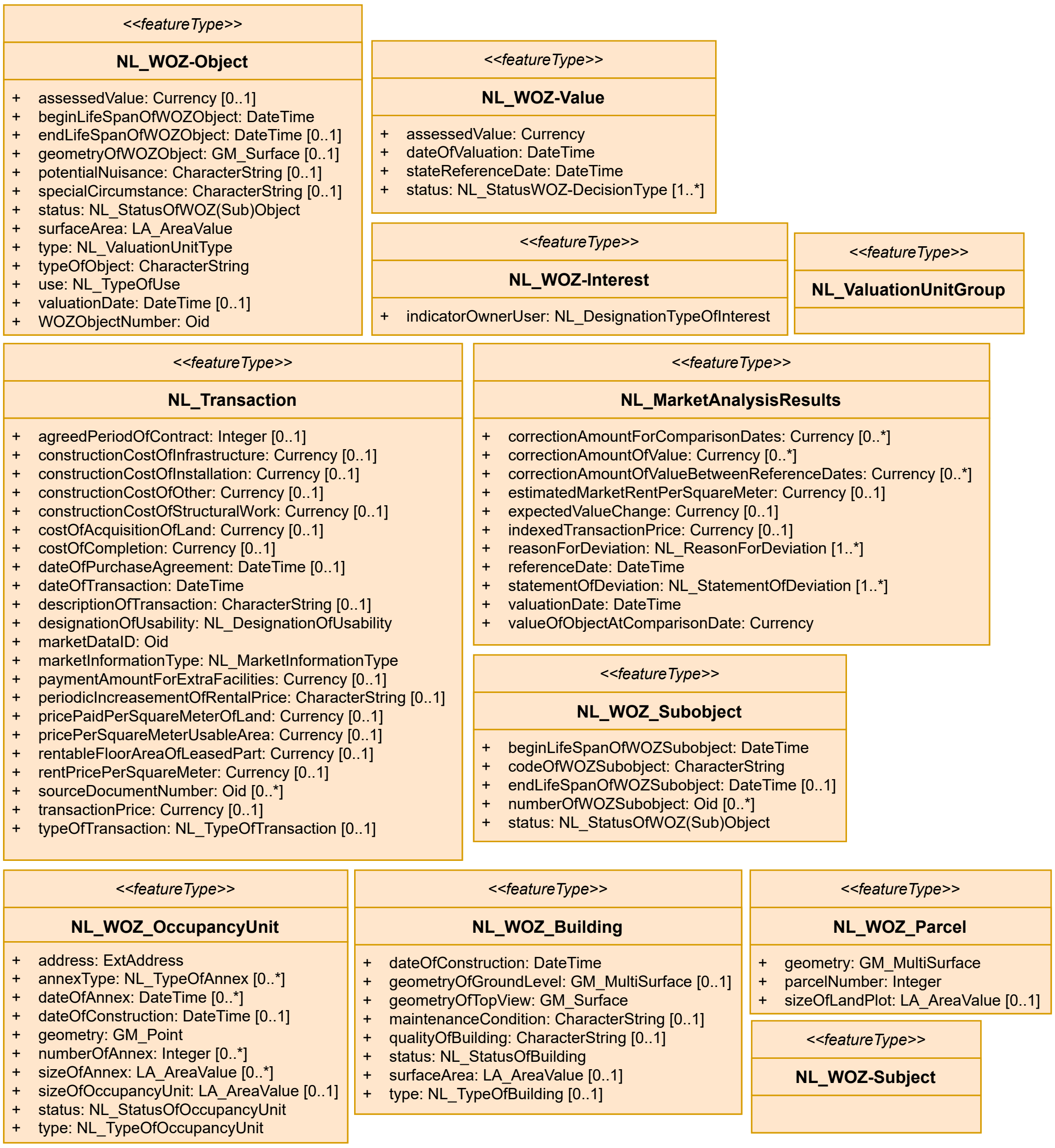


Figure 5.6: Attributes of country specific classes of the country profile for valuation information

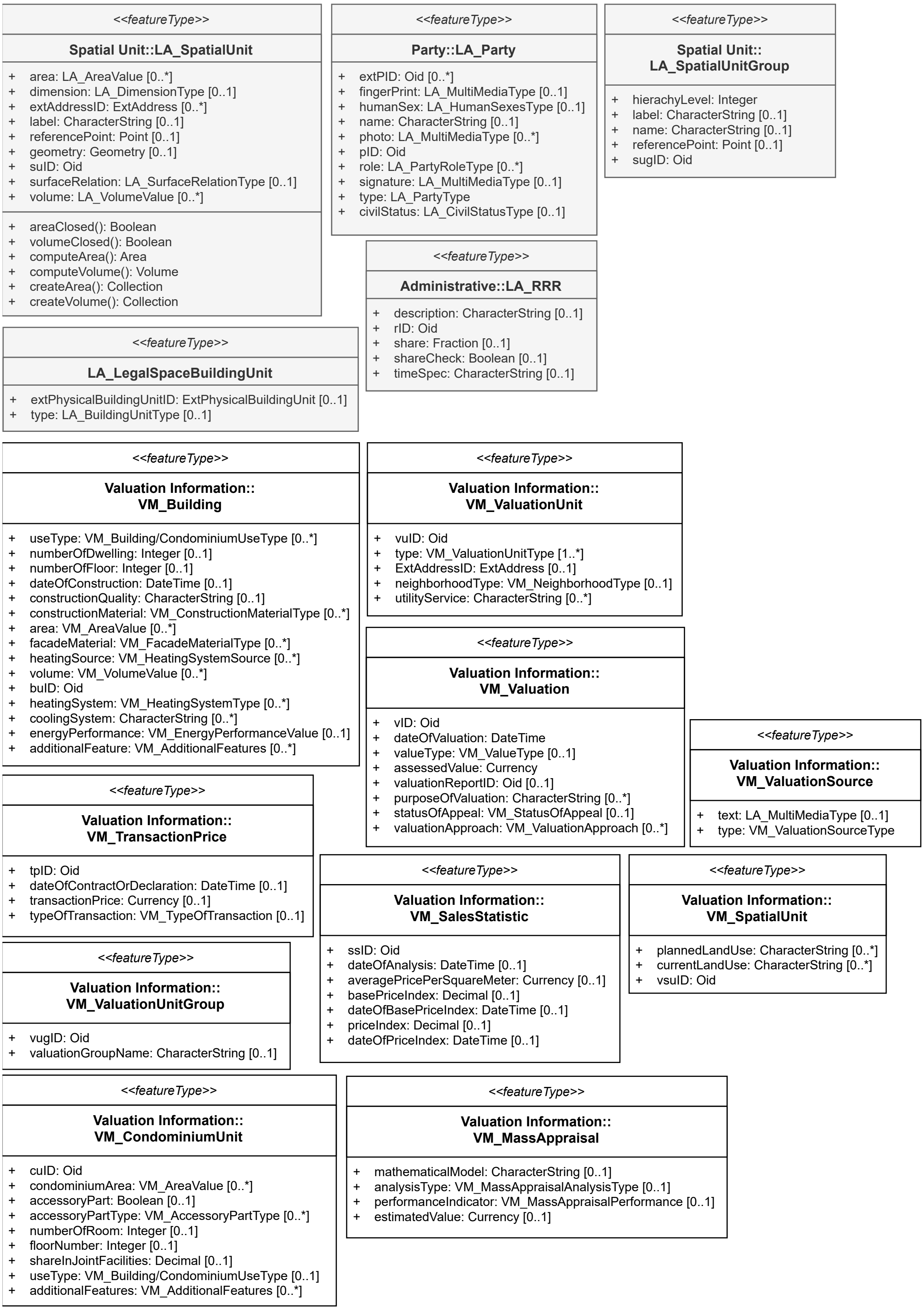


Figure 5.7: Attributes of general classes of the country profile for valuation information

There are two types of objects related to property valuation: WOZ-object and WOZ-subobject. These objects are associated with parcels, buildings, and occupancy units. The WOZ-objects, which are valuation objects, may differ from the BAG-objects. A WOZ-object can contain multiple BAG objects and cadastral parcels. As a result, the WOZ-subobject was created. A WOZ-object contains one or more WOZ-subobjects. A subobject can be a (part of a) parcel, a (part of a) BAG building, or a (part of a) BAG occupancy unit, and can be linked to the BAG or BRK. The main difference between BAG and WOZ is that BAG defines buildings physically, by determining their boundaries, while WOZ defines them functionally, by identifying who uses and owns the space for what purpose. If adjacent buildings or parcels of land are owned and used by the same person, they will form a single WOZ object. On the municipal level, WOZ sub-objects are used to address the lack of compatibility between BAG and WOZ objects.

The NL_WOZ-object class is specified as a child class of VM_ValuationUnit. A WOZ object can contain multiple (parts of) BAG objects, including buildings and occupancy units, as well as (parts of) cadastral parcels. Additionally, a WOZ-object can contain one or more WOZ-subobjects. A WOZ-subobject comprises a (part of a) parcel, a (part of a) BAG building, or a (part of a) BAG occupancy unit.

The VM_ValuationUnit class represents the fundamental recording unit of valuation registers. It defines common characteristics for the valuation objects, such as parcel, property, building, and building unit. The class has relations with the VM_SpatialUnit, VM_Building, and VM_CondominiumUnit classes, which specify the characteristics of the valuation objects by inheritance. These classes are related to NL_ValuationUnit, NL_SpatialUnit, NL_WOZ_Building, NL_WOZ_OccupancyUnit, NL_WOZ-object, and NL_WOZ-subobject classes for developing the country profile of the Netherlands.

The VM_SpatialUnit class represents cadastral parcels, including sub-parcels, for property valuation purposes. The current land use attribute indicates the current use of a cadastral parcel, while planned land use indicates its future use as specified in spatial plans. The class NL_WOZ_Parcel extends the VM_SpatialUnit class to cover parcel characteristics used in property valuation activities in the Netherlands.

The class LA_SpatialUnit in core LADM is related to the VM_SpatialUnit, VM_Building, and VM_CondominiumUnit. These classes represent the characteristics of parcels, buildings, and building units used in valuation. For the country profile of the Netherlands, these classes are related to the NL_WOZ_Parcel, NL_WOZ_Building, and NL_WOZ_OccupancyUnit classes.

The VM_Building class offers a range of standard features for buildings, building components, and other structures that are necessary for property valuation. In the Netherlands, the NL_WOZ_Building class was developed as a subclass of VM_Building, introducing additional features such as ground level geometry, top level geometry, maintenance condition, type, and status.

5.3. Spatial plan information

The country profile of the Netherlands for spatial plan information allows for the recording of data related to the parties involved in spatial plans and the property objects subject to them, including their geometric, legal, physical, economic, and environmental characteristics. The Netherlands has a comprehensive spatial planning system that divides land into various uses, including residential, industrial, agricultural, and natural areas. To create a country profile, an overview of the spatial planning systems, practices and data in the Netherlands is necessary, as was done in Section 2.2.3. Part 5 - Spatial plan information is extended with new classes, characteristics and relationships to cover country-specific needs in spatial planning. The prefix 'NL_' is used for newly added classes for developing the country profile.

Country profile of the Netherlands for spatial planning information Part 5 - Spatial plan information is used as a basis for creating the country profile of the Netherlands for spatial plan information. The resulting country profile of the Netherlands can be viewed in Figure 5.8, together with their classes and attributes that are shown in Figure 5.9. Adjustments to the model are discusses below.

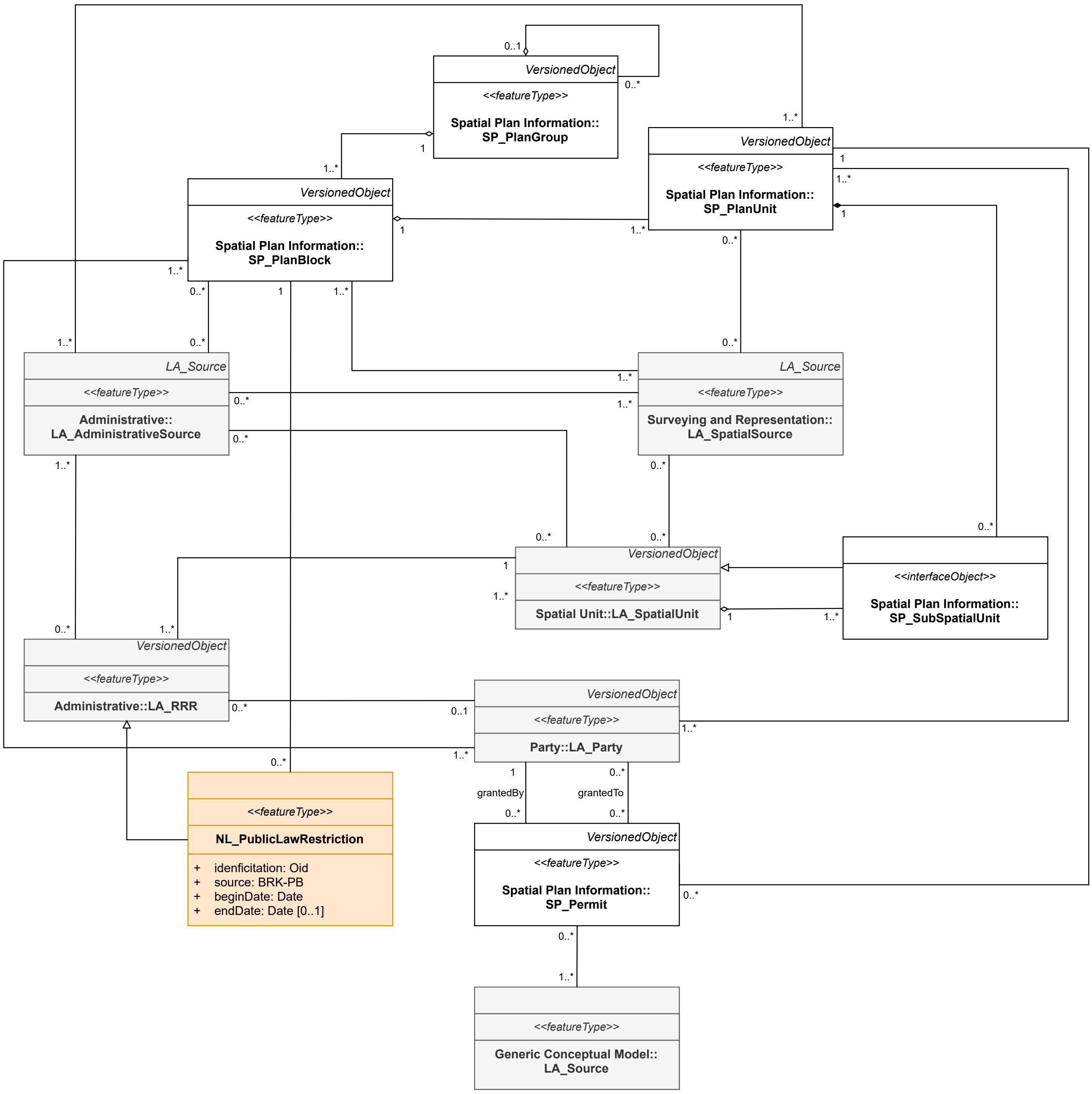


Figure 5.8: Country profile of the Netherlands for spatial plan information

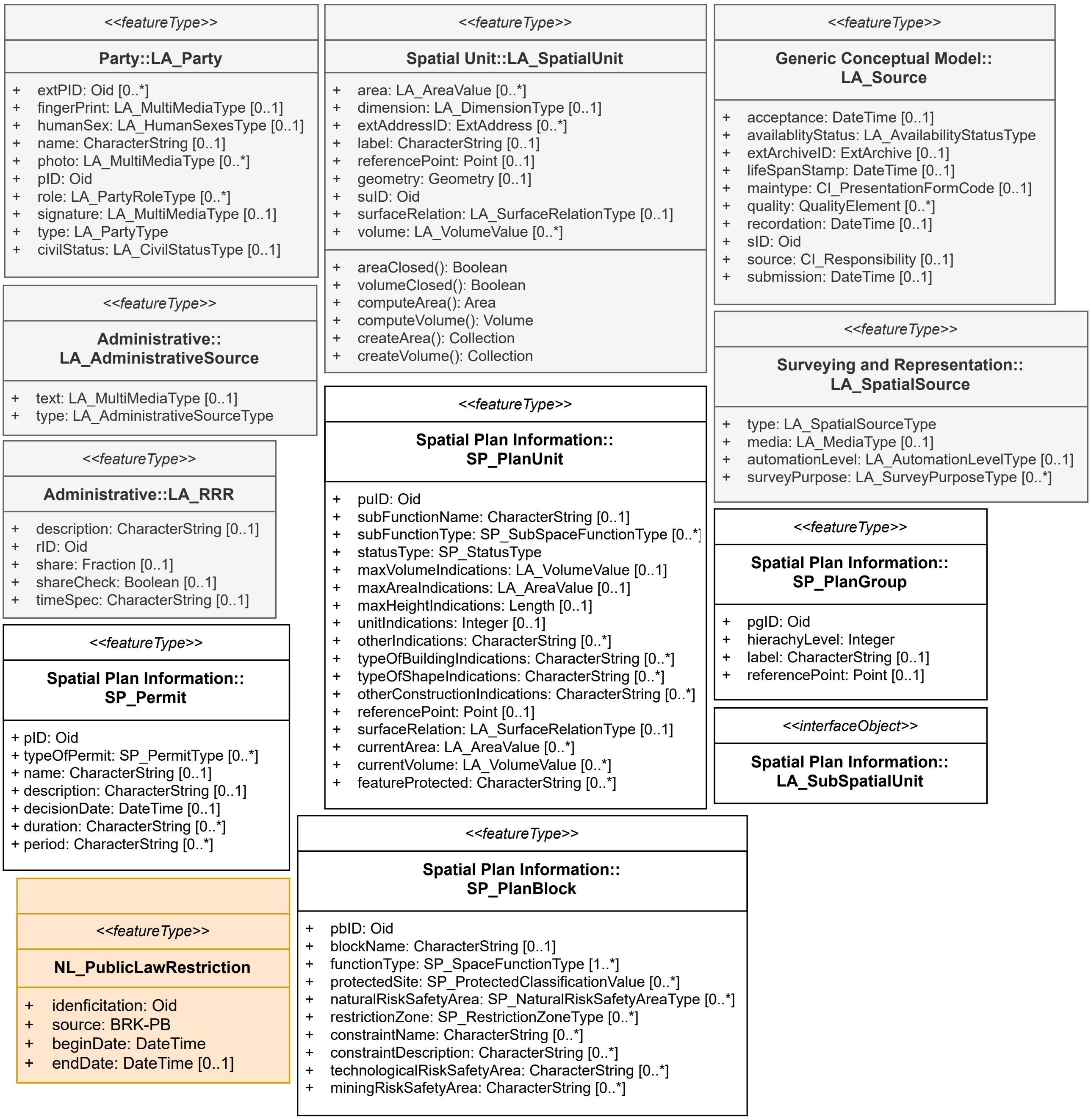


Figure 5.9: Classes and attributes of the country profile of the Netherlands for spatial plan information

Spatial plans are recorded in SP_PlanUnit, which includes the area in 2D/3D with assigned function and purpose to represent land use development according to the spatial planning authorities at the highest level of detail and largest scale, which is usually the municipality. SP_PlanUnit is linked to SP_PlanBlock, indicating the hierarchy of spatial plans, i.e. at the national or local level. This hierarchy reflects the planning process in the Netherlands, which occurs at both national and municipal levels. The model includes these levels, aligning with the country-specific needs.

The class SP_PlanBlock includes recommendations or expected land uses with deontic expressions (i.e. permissible-impermissible, obligatory-omissible, optional, and ought) for activities, uses, or physical developments within a spatial unit.

In the Netherlands, public law restrictions are included within expected land use as defined in SP_PlanBlock. To indicate this, a relationship has been established between the newly added class NL_PublicLawRestriction previously identified in the country profile of core LADM, see Section 5.1. One SP_PlanBlock can contain zero or more public law restrictions, which is indicated in the relationship between the two classes.

This chapter discussed the development of the country profiles for the Netherlands. The country profiles of the Netherlands for core LADM, valuation information and spatial plan information are adjusted to the country-specific needs, and attribute lists of classes are identified. The most apparent adjustments to the LADM model in the development of the country profile are the addition of the classes NL_Address, NL_PublicLawRestriction, NL_RegulatoryArea and NL_SpatialUnitRestriction to the country profile of core LADM. The next chapter will elaborate on the implementation of the developed country profiles with linked data.

6. Implementation with linked data

This chapter discusses the implementation of the country profiles with linked data. Section 6.1 discusses the transformation of the UML country profiles into an OWL ontology model. Hereafter, SPARQL construct queries for the creation of datasets conform the ontology are discussed in Section 6.2. Lastly, Section 6.3 discusses the SPARQL queries to query the data for the use cases and the development of the prototype in the form of a data story.

The purpose of the implementation with linked data is to create a prototype that demonstrates the implementation of LADM in the Netherlands for data dissemination using the developed country profiles of the Netherlands. This chapter discusses the implementation of LADM with linked data. First, the country profiles are transformed into an applicable ontology by translating the UML models into a Web Ontology Language (OWL) ontology model using Protégé. Second, the required datasets for the ontology are created by extracting data from registers, transformation of the data with SPARQL construct queries, and loading the data in a new dataset, by the construction of SPARQL construct queries. Third, new datasets are loaded into the ontology, and lastly the data is queried according to the use cases with SPARQL queries. This last step was carried out using a communicable data story. This system architecture is visualized in Figure 6.1.

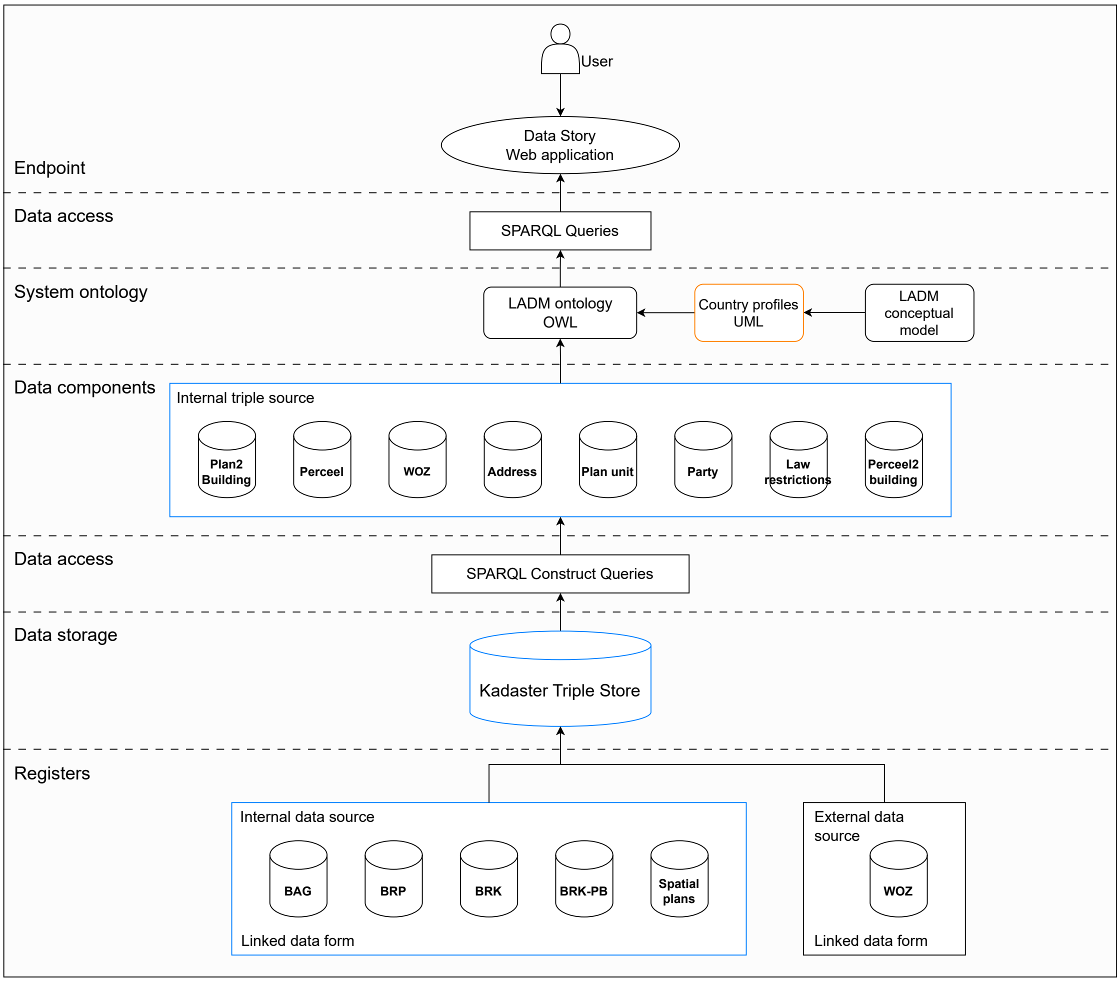


Figure 6.1: System architecture of implementation with linked data

6.1. Ontology

Ontologies in the Web Ontology Language (OWL) are a way to formally model a system's structure by representing its relevant entities and their relationships [Staab and Studer, 2009]. To ensure comprehensibility for those unfamiliar with LADM, three separate ontologies were created: one for core LADM (Part 1 and Part 2), one for valuation information (Part 4), and one for spatial plan information (Part 5). These three ontologies can be linked together. Protégé is an ontology development environment that enables the creation, uploading, and modification of ontologies. Protégé supports the creation and editing of one or more ontologies in a single workspace through a customized user interface. The visualization tools in Protégé allow for interactive navigation of ontology relationships [Stanford University, nd]. Protégé version 5.5.0 is downloaded and used for ontology development in this study. This older version of the software was used due to compatibility issues with the laptop's security settings. It is presumed that this older version should not cause any problems, as this version was previously used for the development of the KKG within the Kadaster with the same functionality.

The first step in developing an ontology is to create the classes. Figure 6.2 shows the classes for core LADM. This is done for all three individual ontologies. Note that there is a hierarchy in classes, subclasses of a class are one hierarchy level lower than the parent class. From Figure 6.2 it can be seen that LA_Mortgage, LA_Restriction and NL_RealRight are one hierarchy level lower than LA_RRR because they are a subclass of the parent class LA_RRR. In turn, NL_PublicLawRestriction is a subclass of LA_Restriction.

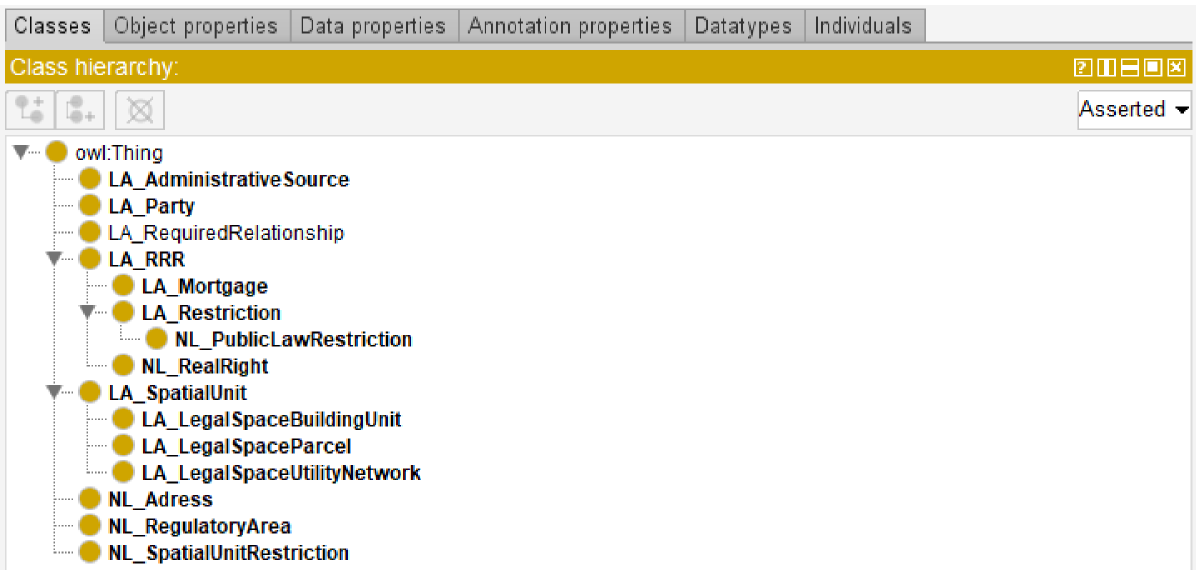


Figure 6.2: Core LADM classes in Protégé

The OWLViz plugin makes it possible to view a graphical representation of the class hierarchy of the OWL ontology, as shown in Figure 6.3.

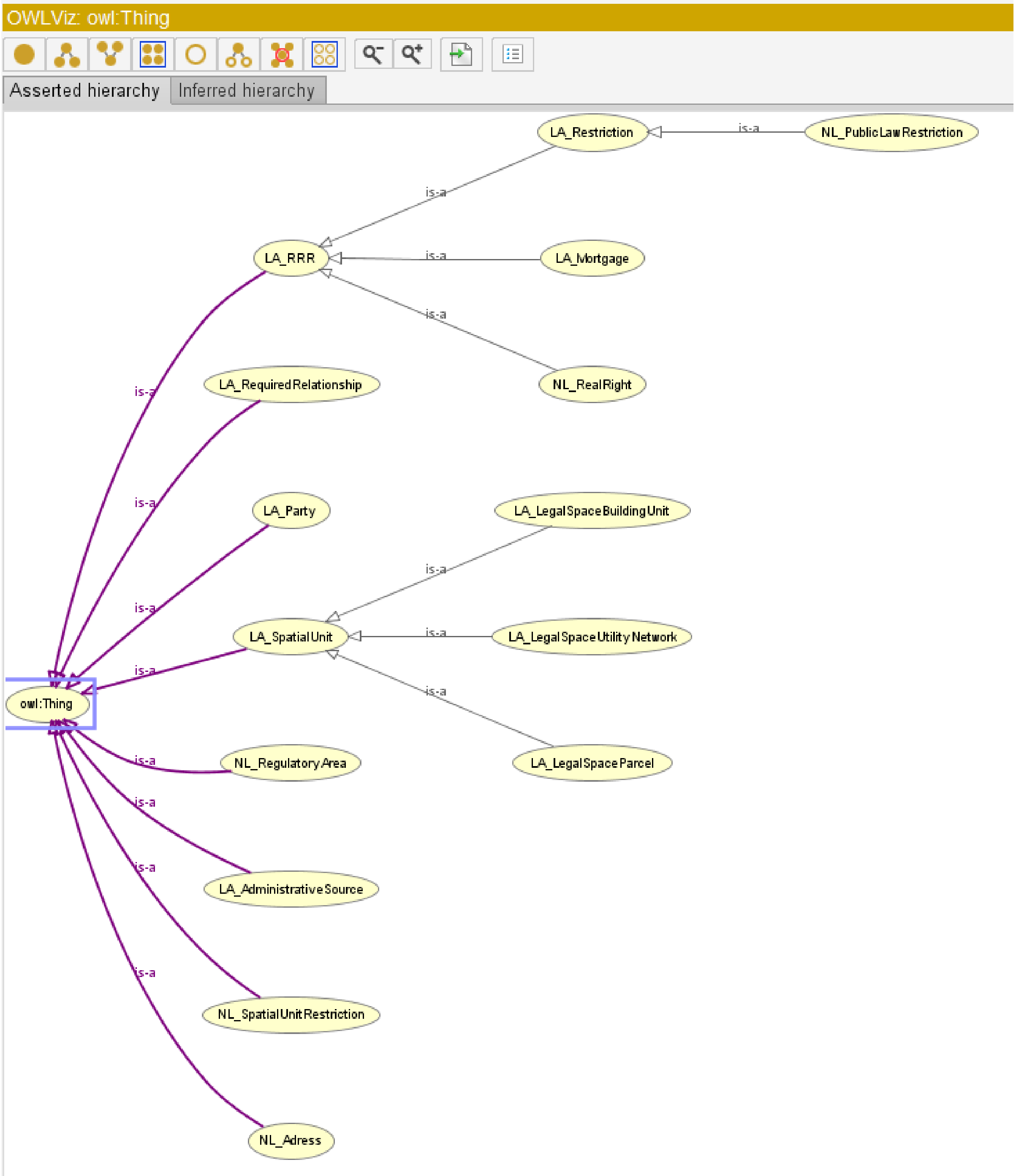


Figure 6.3: Graphical representation of the class hierarchy of core LADM with OWLViz

The next step is to define the relationships between the classes. This is done using object properties as can be seen in Figure 6.4. An object property is defined by defining a name that describes the relationship between the two classes, and by defining the range (a class) and a domain (the class which it has a relationship with). As might be noticed, this has the same structure as RDF triples. Figure 6.5 shows an example of how a relationship between two classes is defined with a data property. The object property 'areAttachedTo' defines that LA_RRR are attached to LA_SpatialUnit. This relationship is now one-way because it has one range and one domain. To also indicate that a spatial unit can contain RRRs, it is necessary to define a new object property with a new range (LA_SpatialUnit) and domain (LA_RRR). Thus, for each relationship line in the UML model, it is necessary to define two object properties in the OWL ontology model.

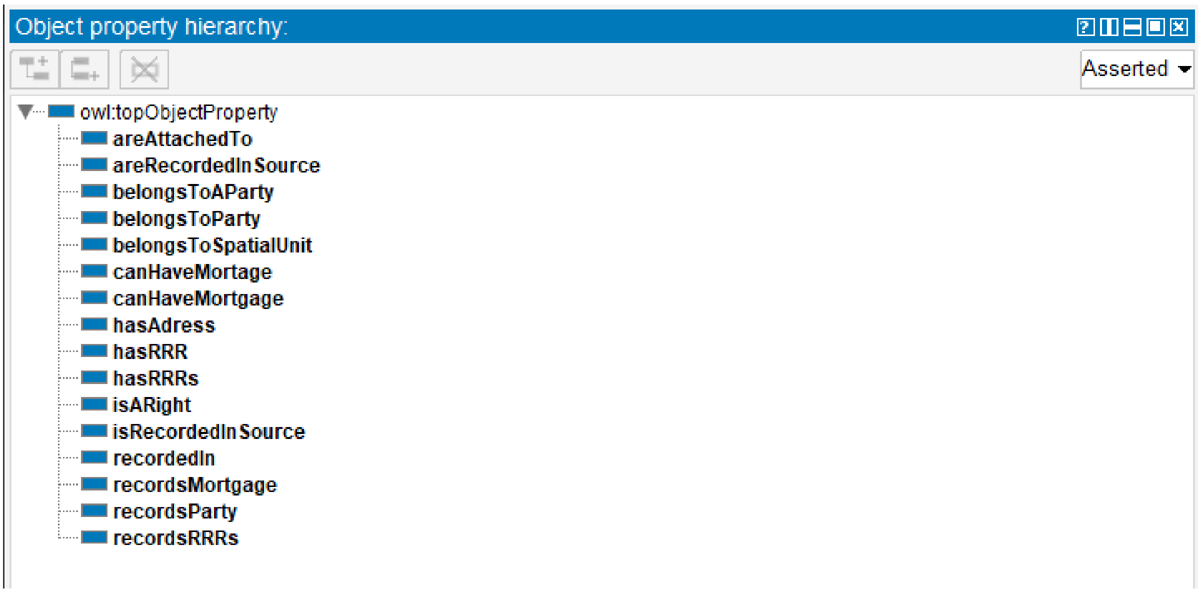


Figure 6.4: Relationships for core LADM in Protégé

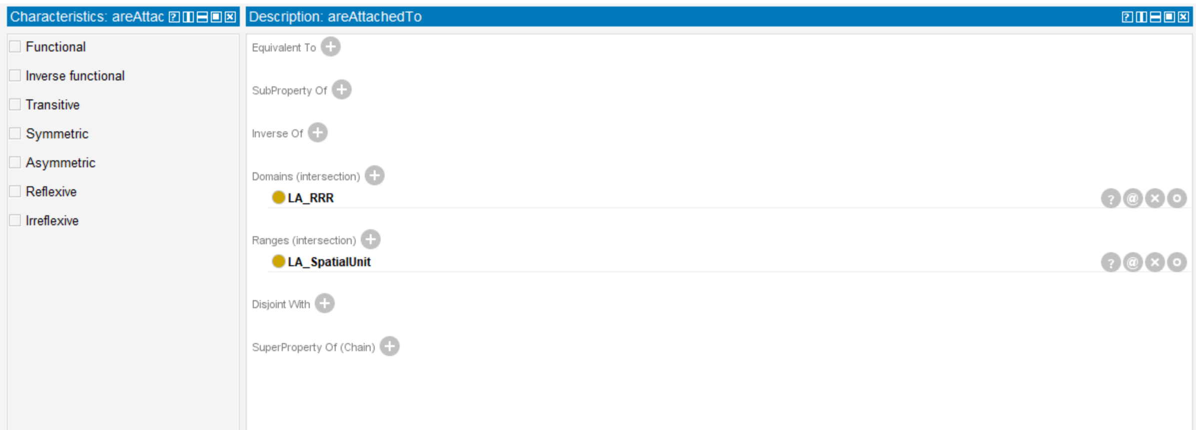


Figure 6.5: Example object property with range and domain

The following step is to impose restrictions as cardinalities on the defined relationships. As shown earlier in Figure 5.2, LA_RRR is bound to exactly 1 LA_SpatialUnit, this kind of restriction is called cardinality. Cardinality refers to relationships between classes and objects and denotes the number of elements. The types of cardinalities are MIN (e.g. 1..* for minimal 1), MAX (e.g. *..1 for maximal 1) and EXACTLY (e.g. 1 for exactly 1). Cardinality is denoted on the range, in this case LA_RRR, by selecting the designated object property, in this case 'areAttachedTo', selecting the applicable cardinality value, in this case exactly 1, and selecting the correct domain class, in this case LA_SpatialUnit. This can be seen in Figure 6.6. A relationship needs a cardinality restriction if indicated in the conceptual UML model.

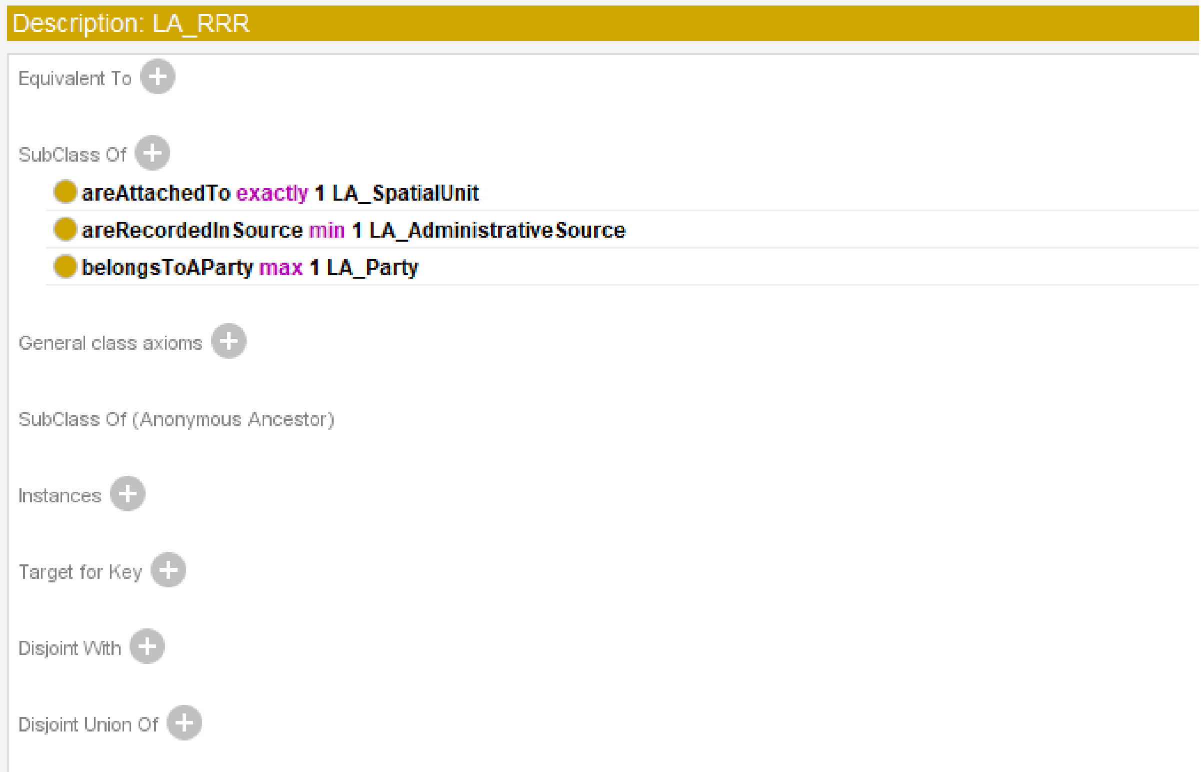


Figure 6.6: Example cardinality of exactly 1

Next, using the classes and their attributes defined earlier during the development of the country profiles, attributes are added per class using data properties, see Figure 6.7 for the data properties of core LADM. A data property is added by giving it the correct name (as defined in the attribute list), determining the domain (the class to which the data property belongs) and defining the range (the data type). Protégé provides a list of default data types from which to choose, which include for example, string, integer, boolean or dateTime. Note that one data property can have multiple domains if this attribute belongs to multiple classes. Nevertheless, the data assigned to this data property will be different per class. A description is added manually to a data property including the type, cardinality and general description. An example in Figure 6.8 shows how the data property 'rID' is defined as a string for the class LA_RRR.

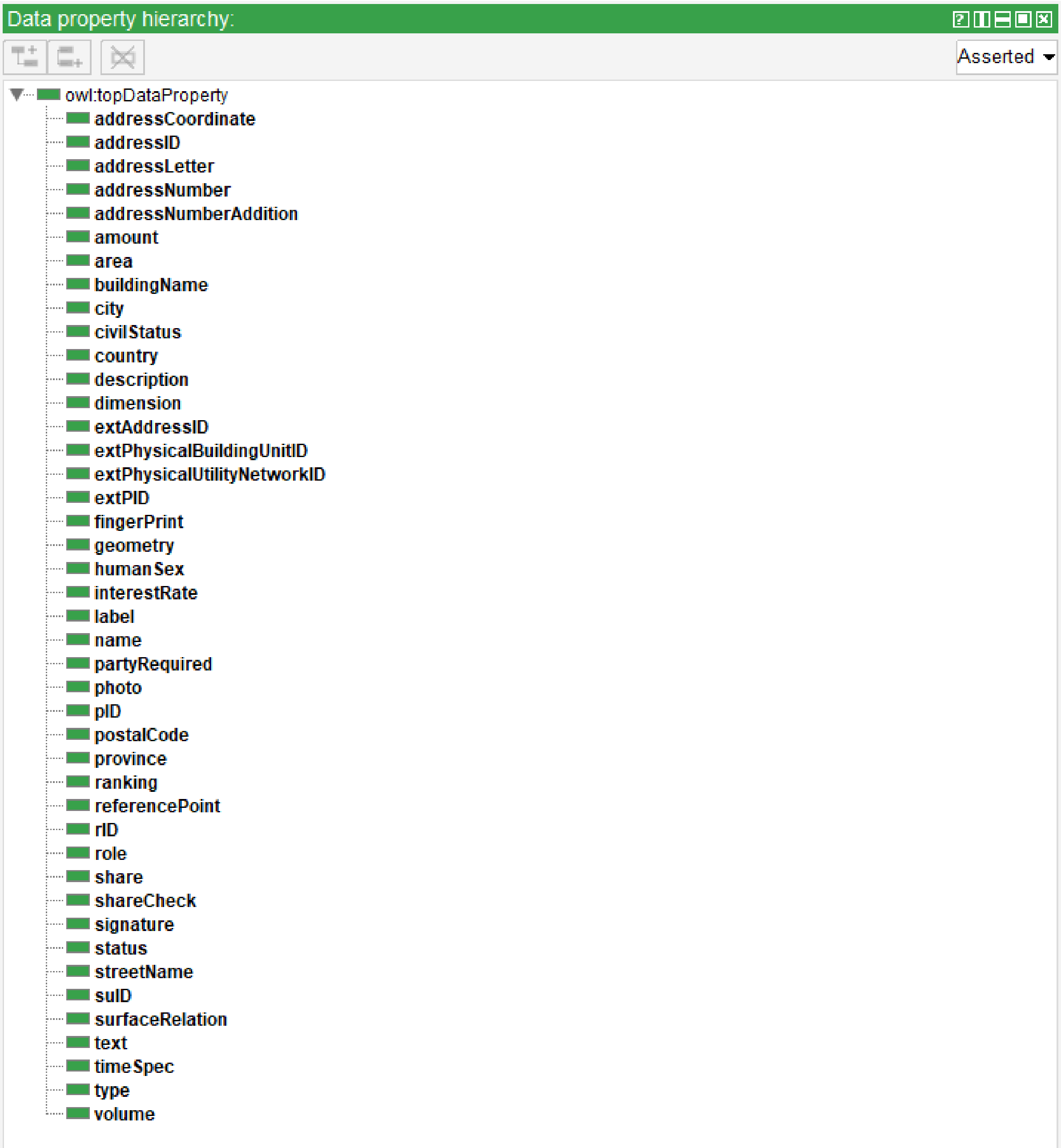


Figure 6.7: Attributes for core LADM in Protégé

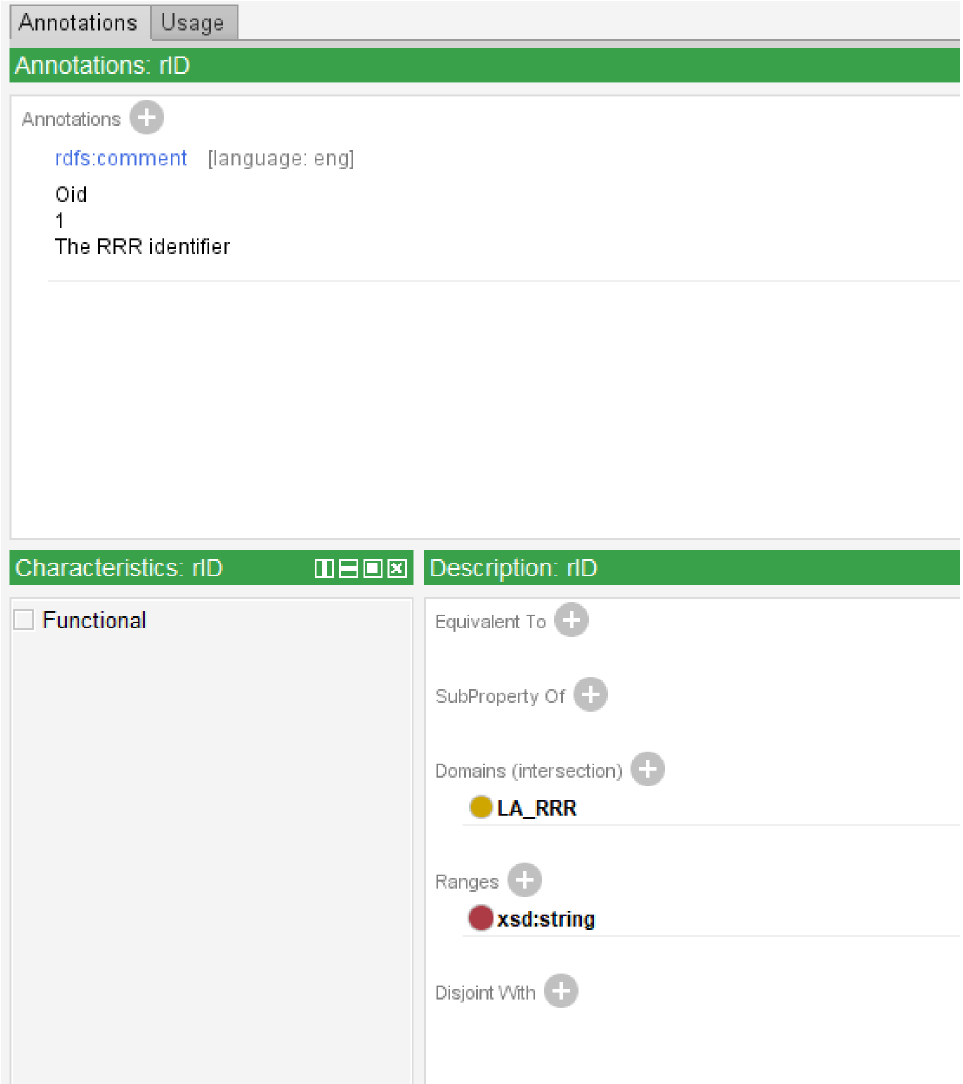


Figure 6.8: Example data property with range and domain

The Triple Store web environment of Kadaster makes it possible to visualize and view the OWL ontology. The resulting ontology for core LADM can be seen in Figure 6.9 and a snippet of this visualization can be seen in Figure 6.10. Clicking on a class shows its attributes and relationships with other classes and their attributes, see Figure 6.11. The cardinalities on the relationships are visualized as empty nodes, which data science experts at Kadaster pointed out is correct, although it can be visually confusing. Figure 6.12 shows how a subclass is visualized with an arrow instead of a line. For the clear individual classes with their attributes and relationships to other classes, please refer to Appendix B.

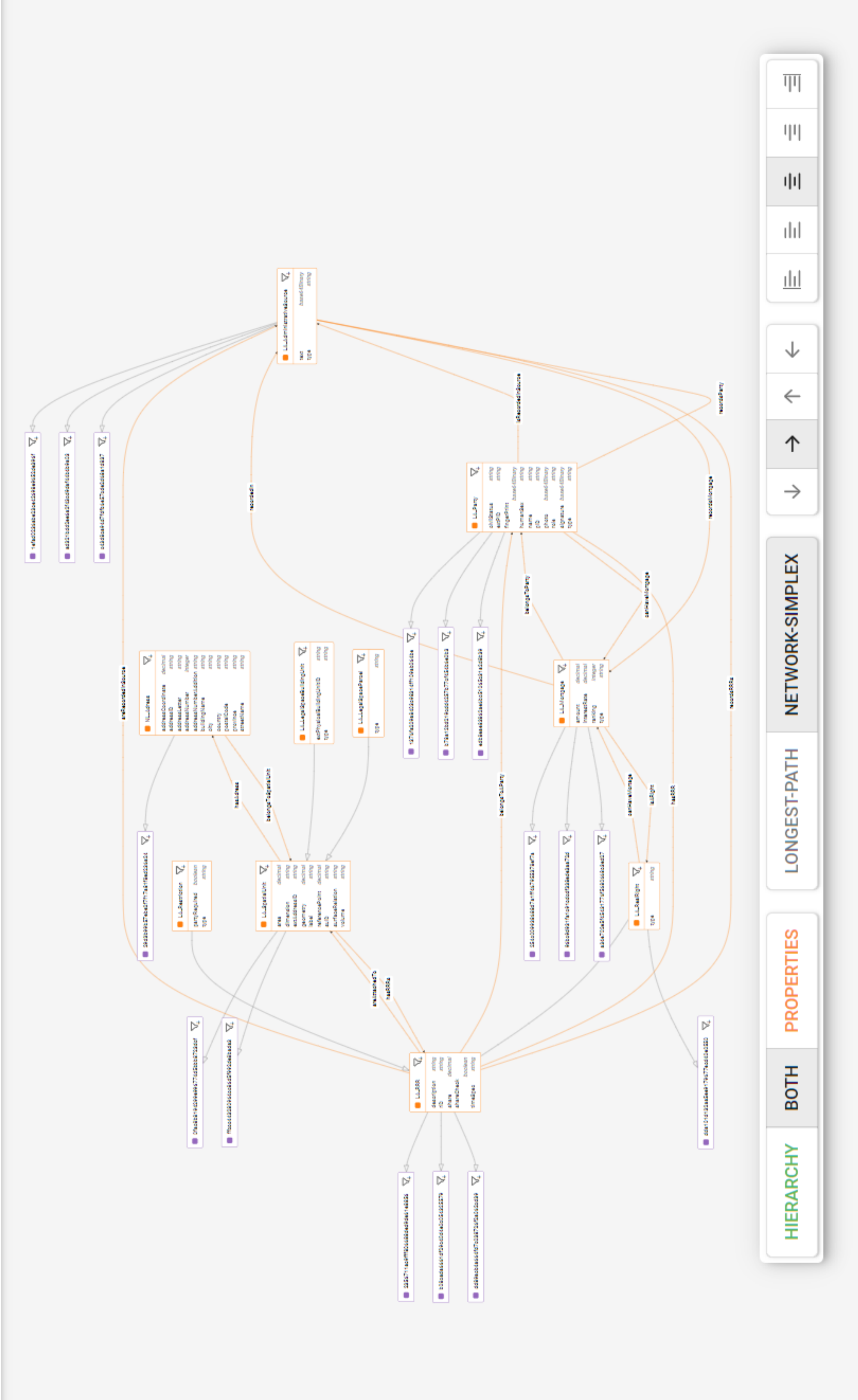


Figure 6.9: Ontology visualization core LADM

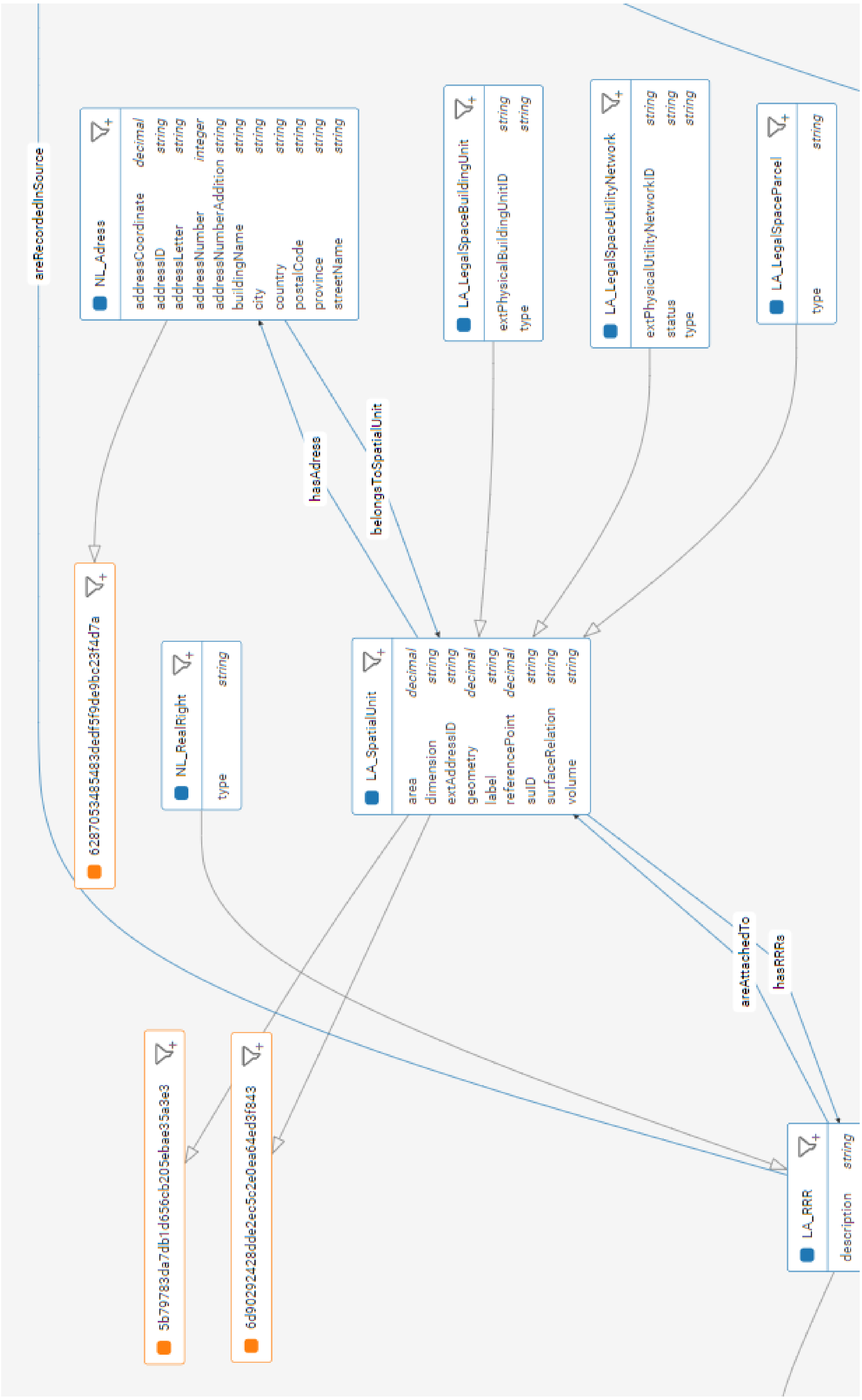


Figure 6.10: Snippet of ontology visualization core LADM

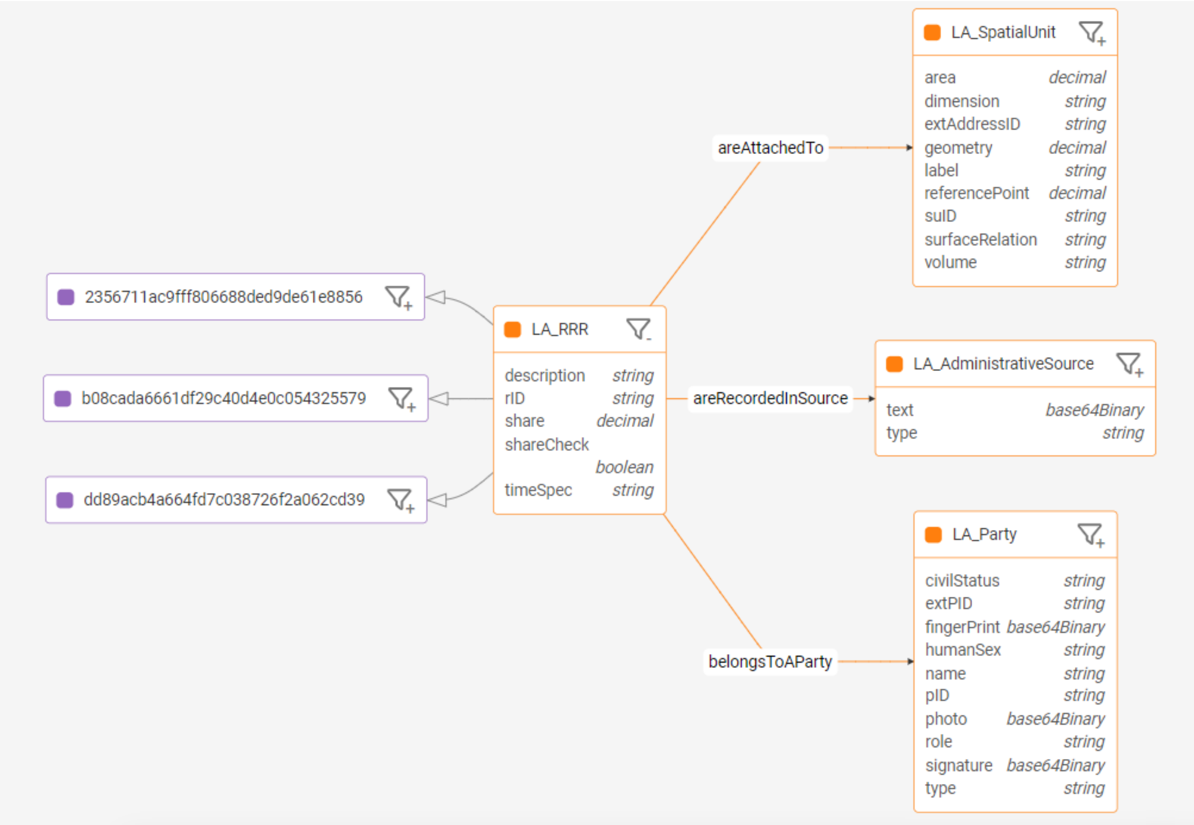


Figure 6.11: LA_RRR and its attributes and relationships

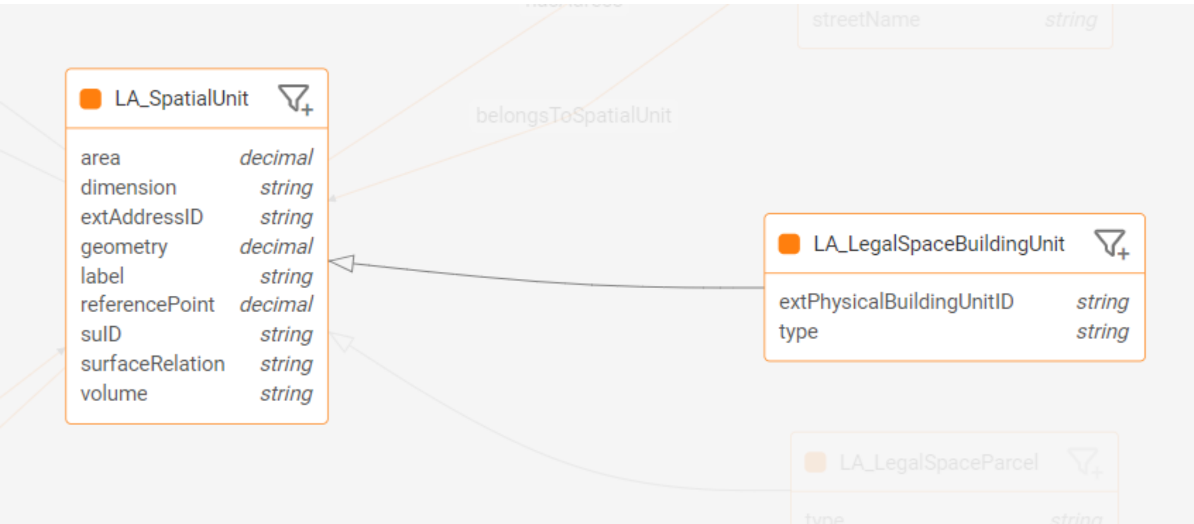


Figure 6.12: Visualization subclass LA_LegalSpaceBuildingUnit

After creating the three individual OWL ontology models, they can be merged using the 'Merge' tool in the 'Refactor' tab of Protégé. This tool enables the copying of classes, object properties, and data properties to an existing ontology, merging them together. However, it is not possible to merge classes with identical names using this tool. To create an accurate model, it is necessary to manually combine classes with identical names, e.g. LA_Party, from the separate models. Additionally, their relationships must be manually transferred to this (new) class. This was also done in the creation of the resulting OWL ontology model for this study. The resulting ontology can be seen in Figure 6.13. The ontology is such extensive that the classes are not readable in the figure, for the individual classes with their attributes and relationships to other classes is referred to Appendix B.

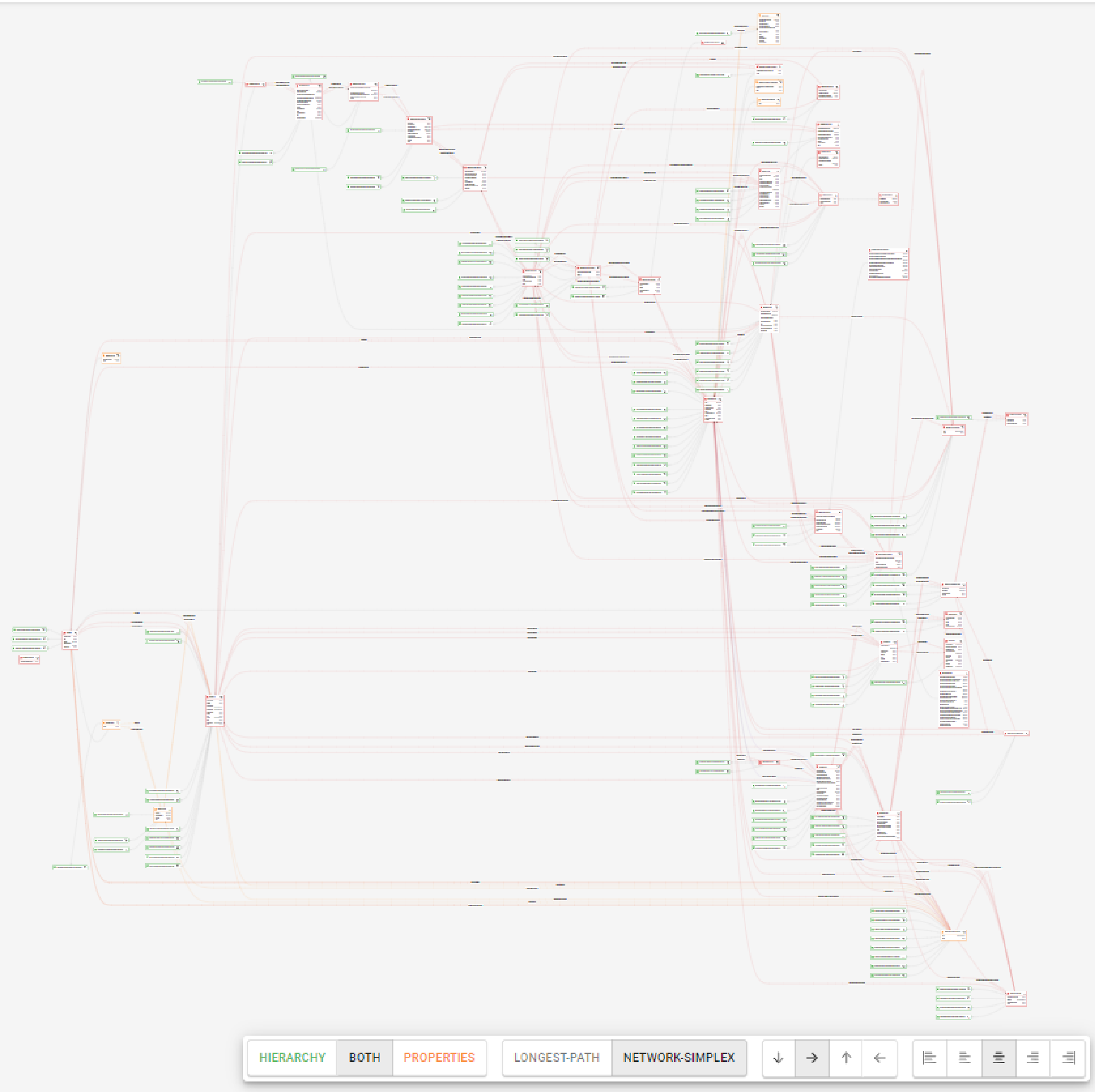


Figure 6.13: Ontologies merged into one ontology model

6.2. SPARQL construct queries

The linked data implementation employs ETL (Extraction, Transformation and Load) to create datasets conform the ontology. This approach is put into practice in the next step, when new datasets conforming to the ontology are created. First, data is extracted from the Dutch registers, then the transformation of the data into a new dataset is done with SPARQL construct queries, and the resulting datasets are loaded into the ontology. While SPARQL queries are used to retrieve data from RDF datasets, SPARQL construct queries are used to create new RDF datasets. This ETL approach, as visualized in Figure 6.14, is discussed in more detail below.

Figure 6.14: Extract, Transformation, and Load approach

For classes and their attributes in the ontology that are not one-to-one identical with the registers in the Netherlands, it is necessary to create new datasets in order to provide the classes in the ontology with the correct dataset. For each class in the ontology, it is therefore necessary to check whether this class exists in the Dutch registers and whether it has the same attributes. If not, a new dataset needs to be created. The new datasets are to be created by compiling data from Dutch registers to match the required attributes in the class that appears in the ontology. The compiling of this data is done using SPARQL construct queries. It is important to ensure that the data used for the creation of new datasets for this linked data implementation is available in linked data format, thus in triples. Note that this step could have been performed simultaneously with the development of the ontology, because the creation of the datasets depends on the individual classes and attributes, and not on the OWL ontology and relationships between the classes.

Creating new datasets can be a time-consuming task, as it requires a thorough understanding of the relationships between classes and attributes in the Dutch registers. This knowledge is necessary to extract the correct data using construct queries and compile it into a new dataset. Also, some classes in the ontology contain attribute information from multiple registers. For instance, the BAG registers house numbers and street names, while the BRK registers the year of construction, which are both part of the same class NL_Address.

It is unnecessary to include and load every dataset in the ontology for the demonstration of the use cases in this study. For example, NL_LegalSpaceUtilityNetwork is not relevant to this study as it pertains to underground networks which are outside the scope of this study. Due to the limited time span of this study, an overview was created to identify the necessary classes and attributes for the querying of the use cases, as can be seen in Table 6.1. This selection is based on the process models of the use case earlier developed in Chapter 4, to demonstrate the implementation of LADM.

NL_Address	**LA_Party**	**LA_LegalSpaceParcel**	**NL_WOZ-value**	**NL_PublicLawRestriction**	**SP_PlanUnit**
houseNumber	identifier	parcelIdentifier	WOZ-object number	publicLawIdentifier	spatialPlan
houseLetter	firstName	geometry	WOZValue	regulatoryArea	designatedArea
houseNumberAddition	lastName	areaSize	dateOfValuation	publicLawRestriction	geometry
streetName	gender			beginDate	
postalCode	bsn			endDate	
cityName	civilStatus				
purposeOfUse					
surfaceArea					
constructionYear					
geometry					

Table 6.1: Overview necessary classes and attributes for the two selected use cases

To create the datasets for these classes, data is extracted from the following datasets, which are available as linked data in the Kadaster Triple Store:

- BAG LV
- BRP (fake data)
- Ruimtelijke plannen
- BRK
- BRK-PB
- WOZ (fake data)

The SPARQL construct queries follow a fixed structure and are written and stored in Kadaster's Triple Store. A query starts with PREFIX statements, which define prefixes for URIs, making the query shorter and more readable. These URIs are used to identify entities in RDF. Next, a CONSTRUCT block is created to define the patterns of triples that will be generated as a result of the query. Finally, a WHERE block is created which contains the patterns used to retrieve data from the source dataset. These patterns define the data to be retrieved and how to match it to obtain the desired information. The retrieved data is linked to the triples in the construct block using a variable denoted by a '?'. In addition, bind statements are used to create a new variable by constructing a URI based on other variables in the query. Below a relatively simple query is demonstrated and explained in more detail.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX woz: <https://data.labs.kadaster.nl/ladm/woz/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

CONSTRUCT {
  ?wozURI
    a ladm:LA_WOZ-Value ;
    ladm:WOZvalue ?wozwaarde ;
    ladm:dateOfValuation ?datum ;
    ladm:NL_relatesToSpatialUnit ?buildingUnitURI .
}
WHERE {
  ?woz
    woz:assessedValue ?value ;
    woz:dateOfValuation ?datum ;
    woz:relatesToSpatialUnit ?vbo .

  bind(strafter(str(?vbo), 'Verblijfsobject.') as ?buIdentificatie )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/value/', str(?buIdentificatie))) as ?wozURI )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/building-unit/', str(?buIdentificatie))) as ?buildingUnitURI )
}
```

The demonstrated query constructs RDF triples representing WOZ values. The query constructs RDF triples of type 'ladm:LA_WOZ-Value'. Each triple consists of the variable '?wozURI' as the subject, representing the URI of the WOZ value, 'ladm:WOZvalue' with the variable '?wozwaarde', representing the actual value, 'ladm:dateOfValuation' with the variable '?datum', representing the date of valuation and 'ladm:NL_relatesToSpatialUnit' with the variable

'?buildingUnitURI', representing the spatial unit related to the WOZ value. The WHERE clause specifies the conditions that ensure only WOZ values, along with their actual values, valuation dates, and related spatial units, are used to generate these triples. The bind statements are used to create the URIs for the '?wozURI' and '?buildingUnitURI' variables based on the '?buIdentificatie' extracted from '?vbo'. The result of such a query (set of triples) can be visualized as a network as can be seen in Figure 6.15. This visualization shows that an entity has a type, namely LA_WOZ_Value, a date of valuation and a relationship called NL_relatesToSpatialUnit to another entity.

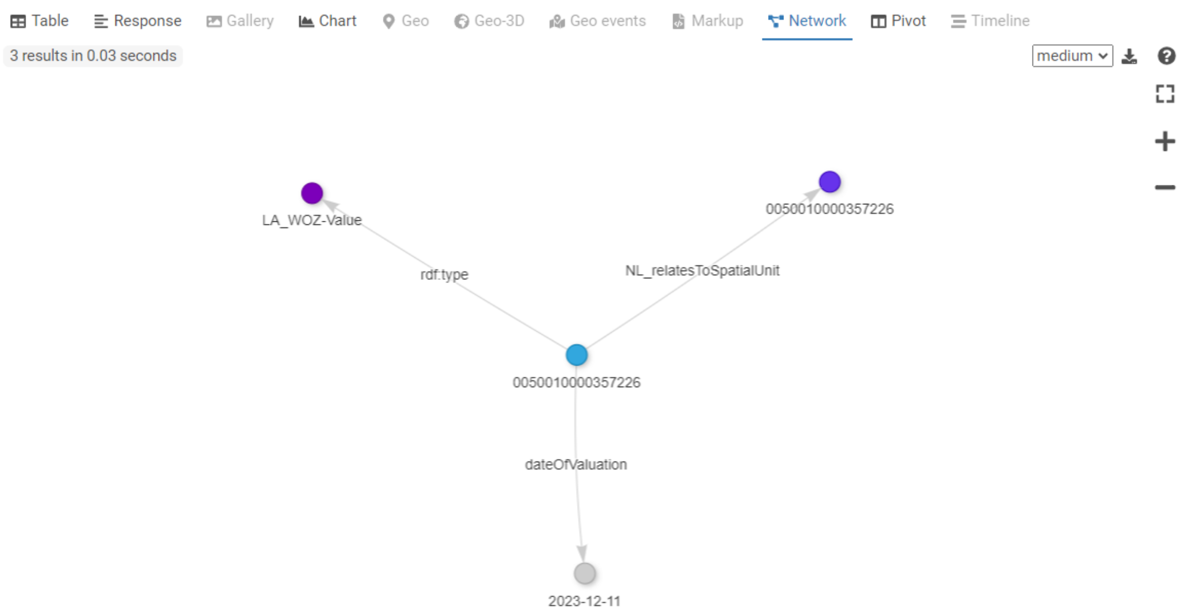


Figure 6.15: Network of WOZ dataset

The complete set of construct queries to create the datasets for this study can be found in appendix C.

During the creation of the datasets using construct queries, it became apparent that the attributes of classes defined by LADM did not always match the data registered in the Dutch registers. As a result of this mismatch, an iteration was carried out on the attributes of classes. For each class, it is necessary to find out which attributes are registered in the Dutch registers, though class attributes defined by LADM may be registered in several registers. This confirmes the requirement of having thorough understanding of the classes and attributes in the Dutch registers is necessary. Figure 6.16 shows the classes with their new attribute list corresponding to the country profile of the Netherlands. Attributes not defined in LADM are prefixed with 'NL_' to indicate that they have been added and are therefore country-specific. Note that not all attributes registered in the Netherlands are added to the attribute list, as only the attributes necessary for the use cases in this study are included. It should also be noted that the attribute lists do not have a one-to-one correspondence with the attributes previously listed in Table 6.1 about the necessary attributes for the selected use cases. This is because during implementation it became apparent that not all attributes were necessary, and in some cases, additional attributes were required.

During implementation, it also became apparent that a direct relationship was missing between spatial plans and spatial unit, respectively, classes SP_PlanUnit and LA_SpatialUnit. Both classes are registered by the same spatial source, however this relationship does not provide any information about the relationship between the two classes. To address this, a direct relationship has been added to the country profile, as can be seen in Figure 6.17 by the orange indicated relationship. The relationship between SP_PlanUnit and LA_SpatialUnit is defined as follows: SP_PlanUnit can include one or more (1..*) LA_SpatialUnit, while LA_SpatialUnit can be included by zero or more (0..*) SP_PlanUnit. This new relationship means that spatial units can now be included in a plan without a spatial source attached. However, this is not possible in the Netherlands because spatial plans are based on spatial data and sources, such as maps, aerial photos, geographic information systems (GIS), and other spatial datasets. To address this issue, the cardinality to LA_SpatialSource is adjusted to 1..* instead of 0..*, indicating that this relationship is required as minimum of 1 spatial source is mandatory. This creates a direct relationship between SP_PlanUnit and LA_SpatialUnit, bypassing the indirect relationship through SP_SubSpatialUnit. It can be stated that there is no need for sub spatial units and thus LA_SpatialUnit and SP_SubSpatialUnit can be merged to create a new class, NL_SpatialUnit. See Figure 6.18 for the merged class.

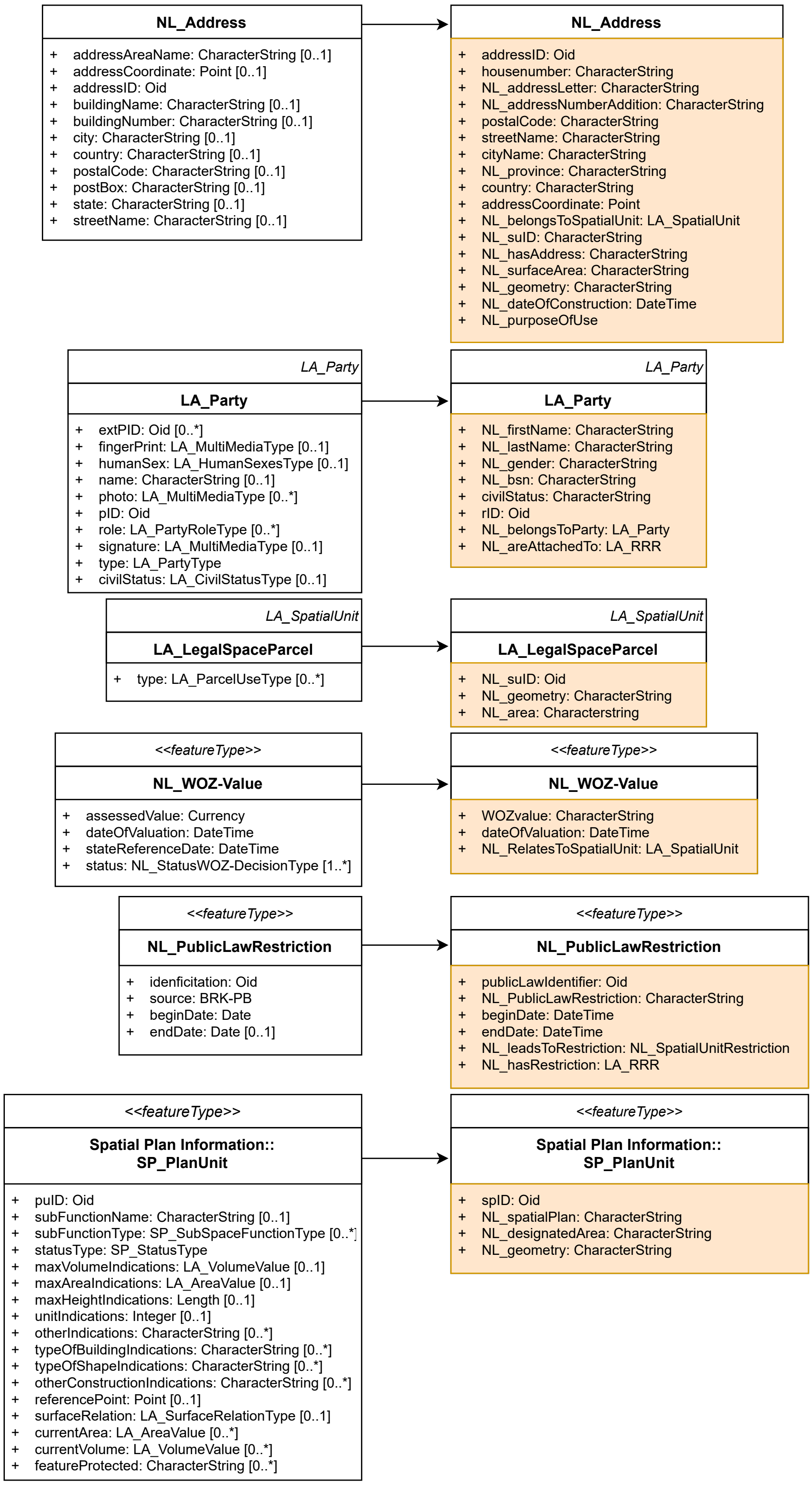


Figure 6.16: Change in class attributes

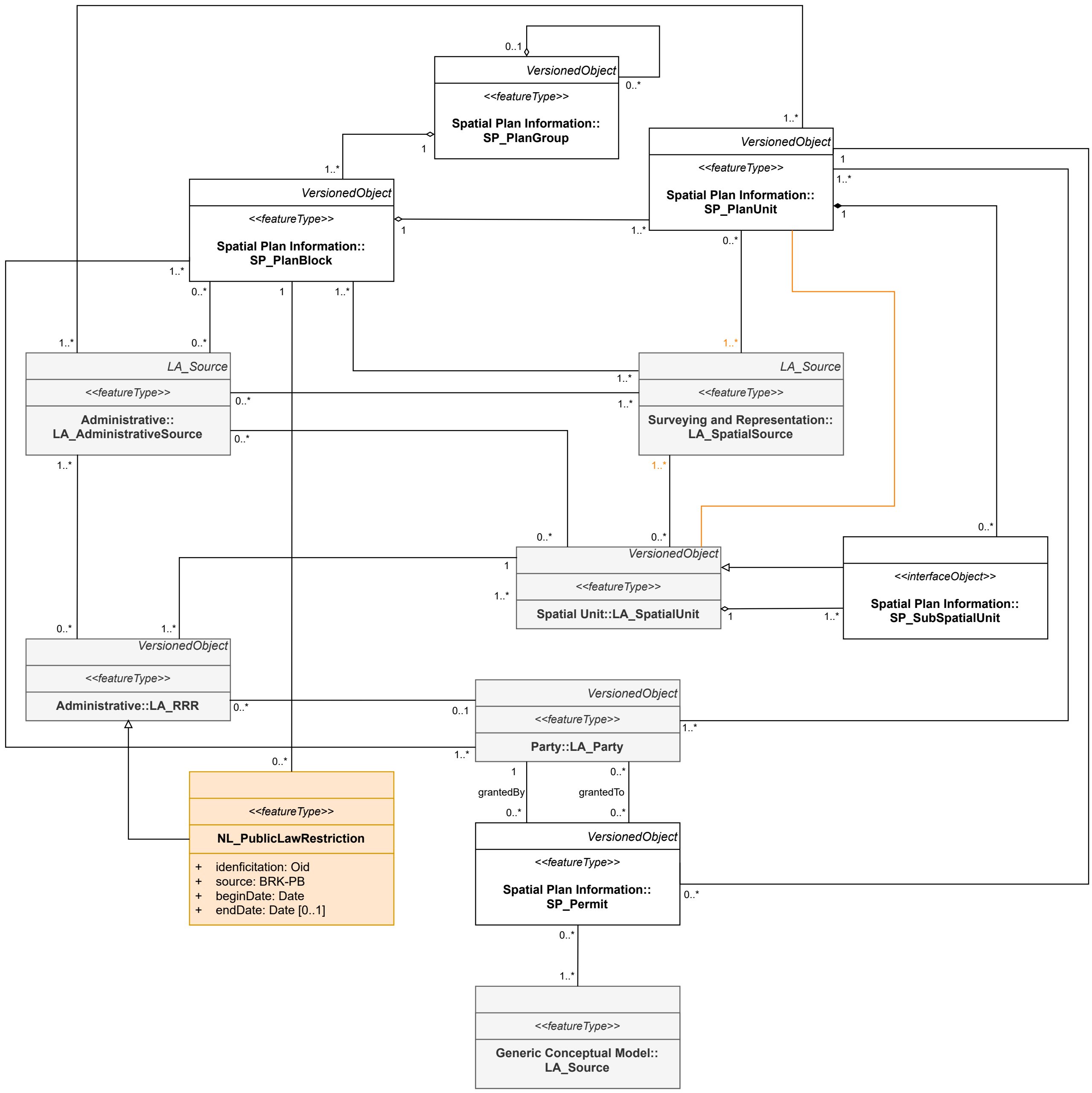


Figure 6.17: Relationship between SP_PlanUnit and LA_SpatialUnit

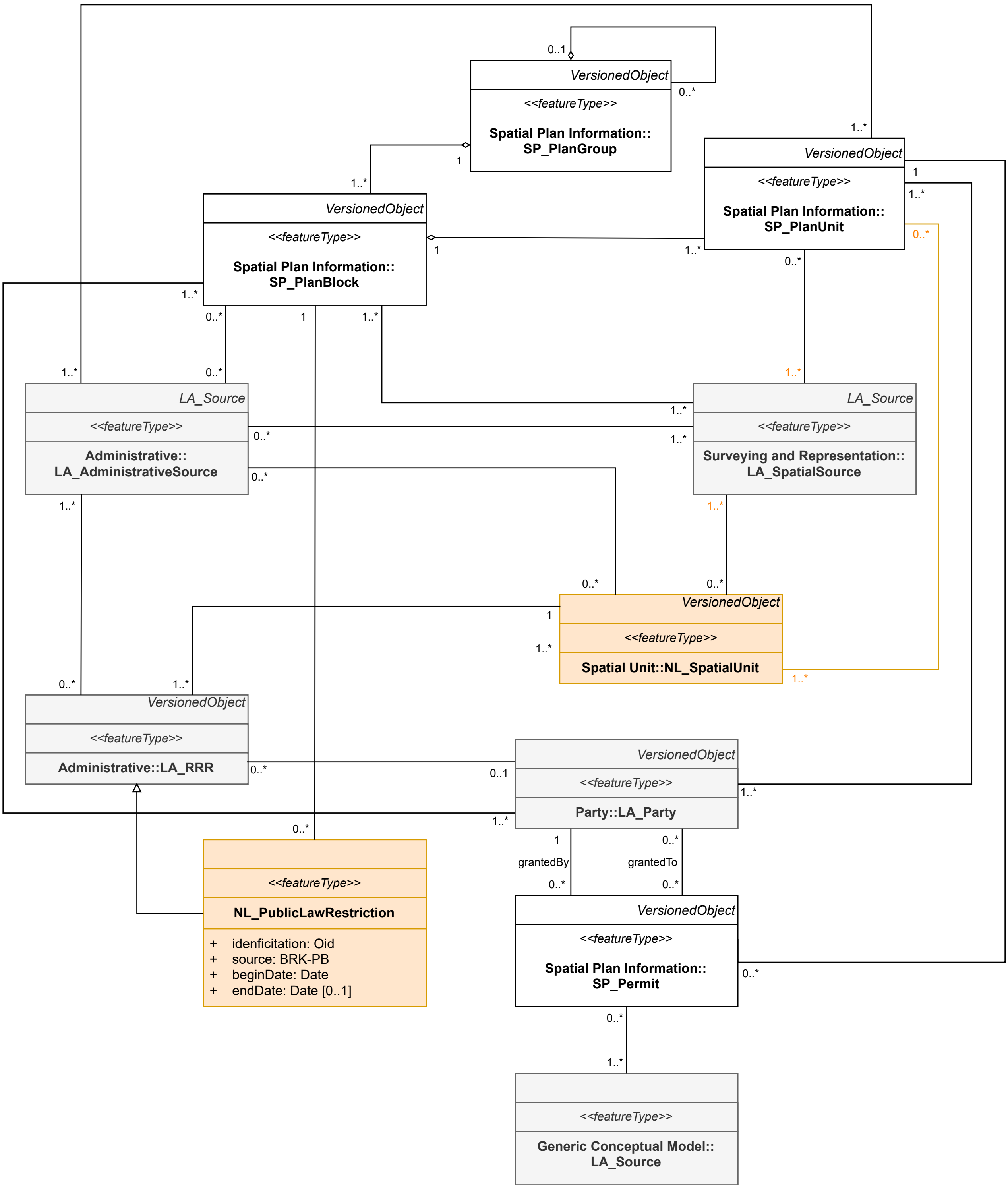


Figure 6.18: Merged classes LA_SpatialUnit and SP_SubSpatialUnit

6.3. SPARQL queries

Now that the ontology has been loaded with the required datasets for the use cases, it is possible to answer the questions defined in the use cases by querying the data using SPARQL queries. The following questions are to be answered by the retrieval of data using SPARQL queries.

Real estate transaction: preliminary phase:

- What is the purpose of use of the property?
- When was the property constructed?
- What is the surface area of the property?
- What are the current property valuations in the area?
- Are there any public law restrictions related to the property?
- What is the surface area of the parcel the property is located on?

The answers to these questions are displayed in a table and the building(s) and parcel(s) are displayed on a map.

Real estate transaction: sequential phase:

- What is the identity of the seller and buyer?
- Are the person's name, address details, and civil status correct and complete?

The answers to these questions are displayed in a table.

Building permit: preliminary phase:

- What spatial plan(s) are attached to a property a building plan is developed for?
- What spatial area does a spatial plan attached to a property apply to?

The answers to these questions are displayed in a table and the area's of spatial plans are displayed on a map.

Building permit: sequential phase:

- Is the personal information on the application in line with the information in the base register of persons?
- What public law restrictions are applicable to the property the proposed building plan relates to?
- What spatial plans are applicable to the address of the proposed building plan?
- What is the cadastral data regarding the property the proposed building plan relates to?
- What spatial area does a spatial plan attached to a specific address apply to?

The answers to these questions are displayed in a table and the building(s) and area's of spatial plan(s) are displayed on a map.

To answer these questions, variables can be filled in. To answer questions relating to address information, it is possible to fill in a postal code, house number, house letter and/or house number addition as a variable, thus requesting only the data relating to the values of those variables. For questions relating to personal information, it is possible to query on a citizen service number (burgerservicenummer) (BSN).

Retrieving information using linked data enables answering these questions. As earlier explained in Section 2.4, linked data utilizes RDF, RDF triples and triple patterns. A SPARQL query searches for specific patterns in the RDF data for the retrieval of information [Picalausa and Vansummeren, 2011]. Such a SPARQL query for the retrieval of specific data is demonstrated and described below. The demonstrated SPARQL query returns personal information and property ownership by address information. The complete set of SPARQL queries for the retrieval of data for the use cases can be found in Appendix D.

```
PREFIX graph: <https://data.labs.kadaster.nl/ladm/ladm-test/graphs/>

SELECT distinct ?bsn ?firstname ?lastname ?civilstatus ?country ?province ?city ?postalcode ?street ?housenumber ?houseletter ?housenumberaddition

WHERE
{
  graph <https://data.labs.kadaster.nl/ladm/ladm-test/graphs/party>
  {
    ?party a <https://data.labs.kadaster.nl/2024/ladm#LA_Party>.
    ?party <https://data.labs.kadaster.nl/2024/ladm#NL_bsn> ?bsn.
    ?party <https://data.labs.kadaster.nl/2024/ladm#NL_firstName> ?firstname.
    ?party <https://data.labs.kadaster.nl/2024/ladm#NL_lastName> ?lastname.
    ?party <https://data.labs.kadaster.nl/2024/ladm#NL_gender> ?gender.
    ?party <https://data.labs.kadaster.nl/2024/ladm#civilStatus> ?civilstatus.

    ?rrr a <https://data.labs.kadaster.nl/2024/ladm#LA_RRR>.
    ?rrr <https://data.labs.kadaster.nl/2024/ladm#NL_belongsToAParty> ?party.
    ?rrr <https://data.labs.kadaster.nl/2024/ladm#NL_areAttachedTo> ?parcel.

     graph <https://labs.kadaster.nl/ladm/graphs/perceel-2-building>
  {
     ?parcel <https://data.labs.kadaster.nl/2024/ladm#NL_isAssociatedWith> ?building.
  }

    graph <https://labs.kadaster.nl/ladm/graphs/address>
  {
     ?adres <https://data.labs.kadaster.nl/2024/ladm#NL_belongsToSpatialUnit> ?building.
     ?adres <https://data.labs.kadaster.nl/2024/ladm#NL_hasAddress> ?echtAdres.
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#postalCode> ?postalcode.
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#cityName> ?city.
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#country> ?country.
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#streetName> ?street.
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#houseNumber> ?housenumber.
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#NL_province> ?province.
```

```
    OPTIONAL{
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#NL_addressLetter> ?houseletter.
    ?echtAdres <https://data.labs.kadaster.nl/2024/ladm#NL_addressNumberAddition> ?housenumberaddition.
     }
    }
  }
}
  limit 10
```

The PREFIX statement is used to assign 'graph' to a URI that refers to a graph environment in the Triple Store of Kadaster. Following, the SELECT statement indicates which variables, indicated by a '?', are to be retrieved, in this case: bsn, firstname, lastname, civilstatus, country, province, city, postalcode, street, housenumber, houseletter and housenumberaddition. The WHERE statement then states where to retrieve the data relating to these variables from.

The 'graph' prefix is used to state the URI of the graph from which data must be retrieved from. Following, a variable '?party' is defined followed by the URI of a class that is located in the graph environment earlier stated by 'graph', in this case the URI leads to a dataset containing information on party. The '?party a <URI>' statement says: give me all instances that are in the dataset of this class. Attribute data inside a class can be retrieved by stating the variable name of the class, in this case '?party', followed by the URI of the attribute. To assign the data of this attribute to a variable, the statement is ended with a new variable, for example '?bsn'. By stating the variable '?bsn' in the SELECT statement, the data relating to this variable is retrieved.

In addition to personal data, it is also requested to acquire ownership data tied to individuals having a BSN, stated by the variable ?bsn. As is known that data on buildings and addresses is not in the same graph as parties, this requires retrieval of information from other graphs, and the linking of these graphs. By defining relationships in the query, a pattern can be formed. The ontology states how the relationship between personal information and ownership information, respectively LA_Party and NL_Address, is as can be seen in Figure 6.19. A party can have RRRs, RRRs are attached to a parcel, a spatial unit is located on a parcel and a spatial unit has an address. Instances of RRR are retrieved by stating a new variable '?rrr' and the URI to its class. The URI stating 'NL_belongsToAParty' indicates the relationship of RRR to a party, indicated by the '?party' variable. Following, the relationship between RRR and a parcel is stated by the URI stating 'NL_areAttachedTo', and the variable '?parcel'. Next the relationship between parcel and building is stated by the URI stating 'NL_isAssociatedWith' and followed by the variable '?building' indicating buildings. Note that this relationship is stored in another graph, which is indicated by the new 'graph' statement and its URI to the correct graph. The last relationship that needs to be defined is between a building and an address. Address information is stored in another graph, thus the 'graph' statement is again used to indicate the URI of the graph where address information is stored. Then the relationship between '?adres' and '?building' is indicated by the URI stating 'NL_belongsToSpatialUnit'. Following, all attribute information from the NL_Address class is retrieved by variables. These variables are stated in the SELECT statement, as it is requested that this data is returned.

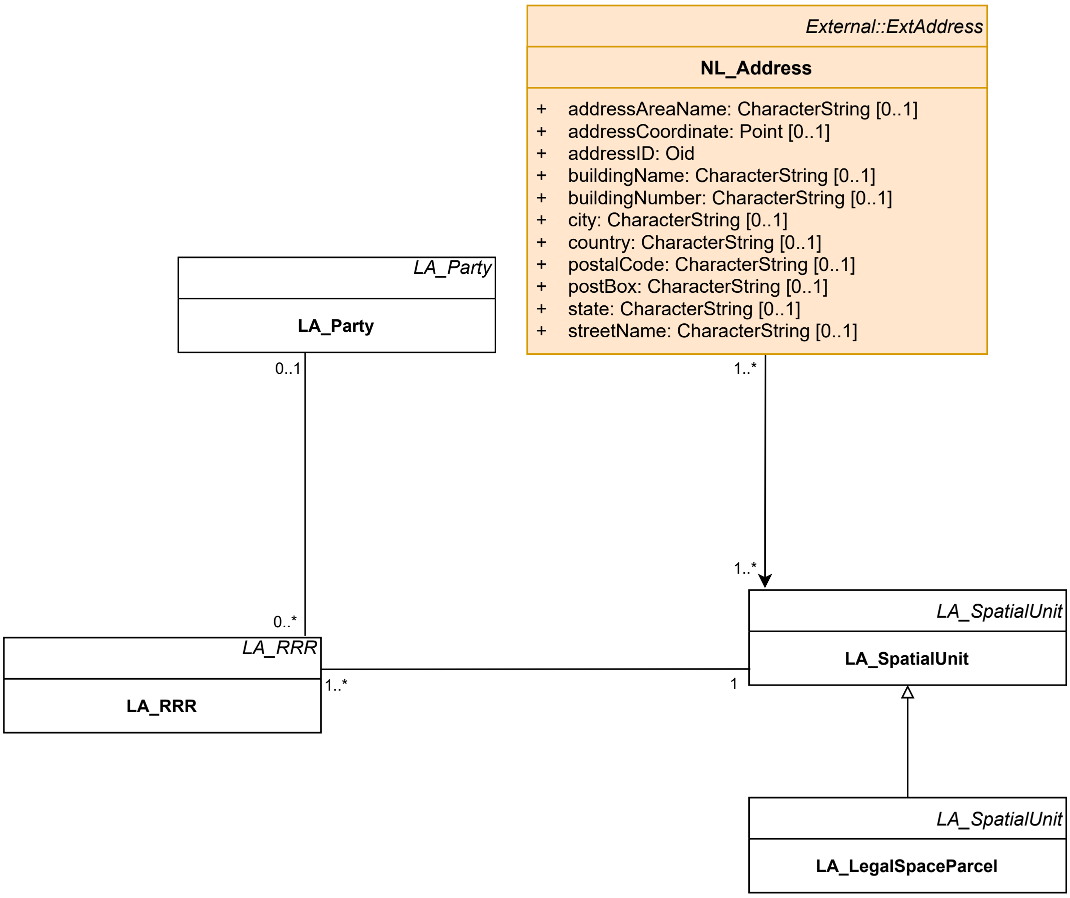


Figure 6.19: Relationships from LA_Party to NL_Address

6.3.1. Data story

Data story telling involves creating a persuasive narrative using intricate data and analytics to inform an audience. Through the use of data storytelling, complex information is simplified to enhance the ability of the audience to engage with the information [Microsoft, nd]. Effective data storytelling can add value to the data by providing additional insights, interpreting complex information, highlighting essential key points, and enhancing a human touch. In essence, a data story provides a real-life example of implementing data. It is a way to demonstrate how data can be used in practice and provides context for possible recommendations [Ironhack, nd]. When creating a data story, it is important to define the purpose of the story. The objective of a data story in this study is to demonstrate the ability to retrieve data from multiple registers simultaneously with the LADM-based approach and linked data. To demonstrate this, the previously defined use cases in Chapter 4 are queried. As two use cases are defined, two individual data stories are created for the real estate transaction and the building permit application, answering the questions in the use cases by the retrieval of data.

Kadaster's Triple Store provides an online web environment for creating a communicable prototype in the form of a data story with SPARQL queries in a simple and effective manner. Variables can be assigned to the queries, enabling interactive querying. For instance, the postal code variable allows users to request building information for specific postal codes. Furthermore, various visualization options, such as tables, graphs or maps can be displayed. Figure 6.20 illustrates how the banner for the real estate transaction data story looks like. Figure 6.21 shows the result of a query returning personal information, and Figure 6.22 shows an example of how the result of a query returning building information is displayed on a map. Note that for displaying data on a map a geometry is required.

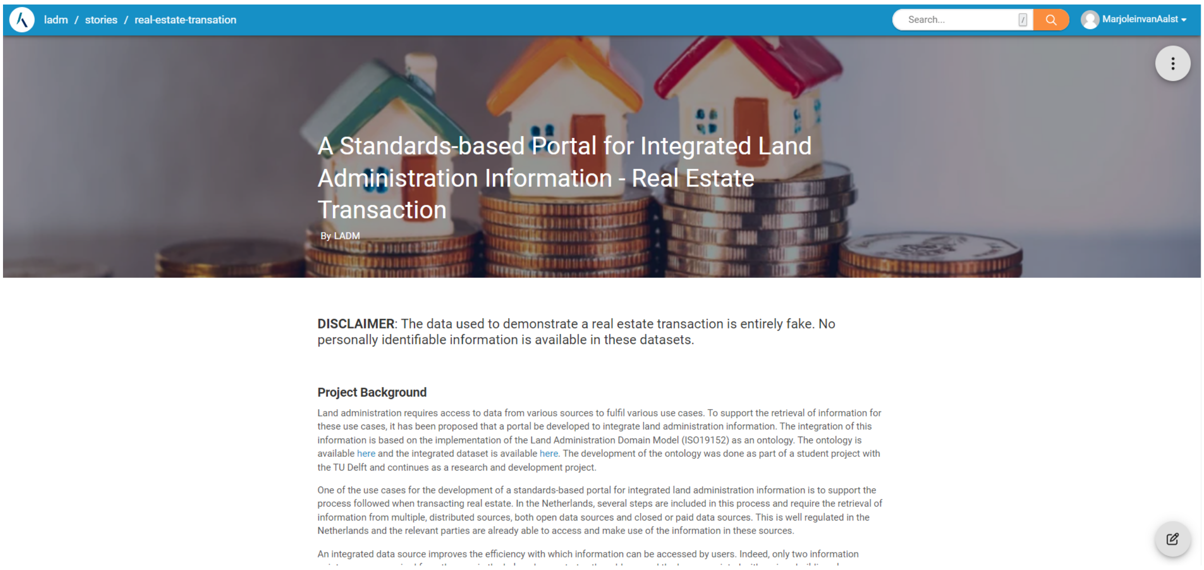


Figure 6.20: Banner data story - Real estate transaction

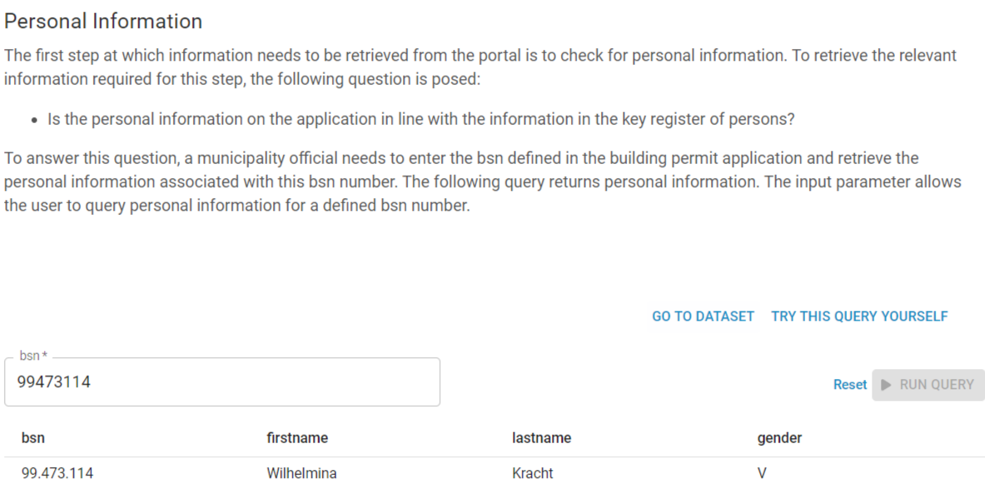


Figure 6.21: Result of query - Personal information

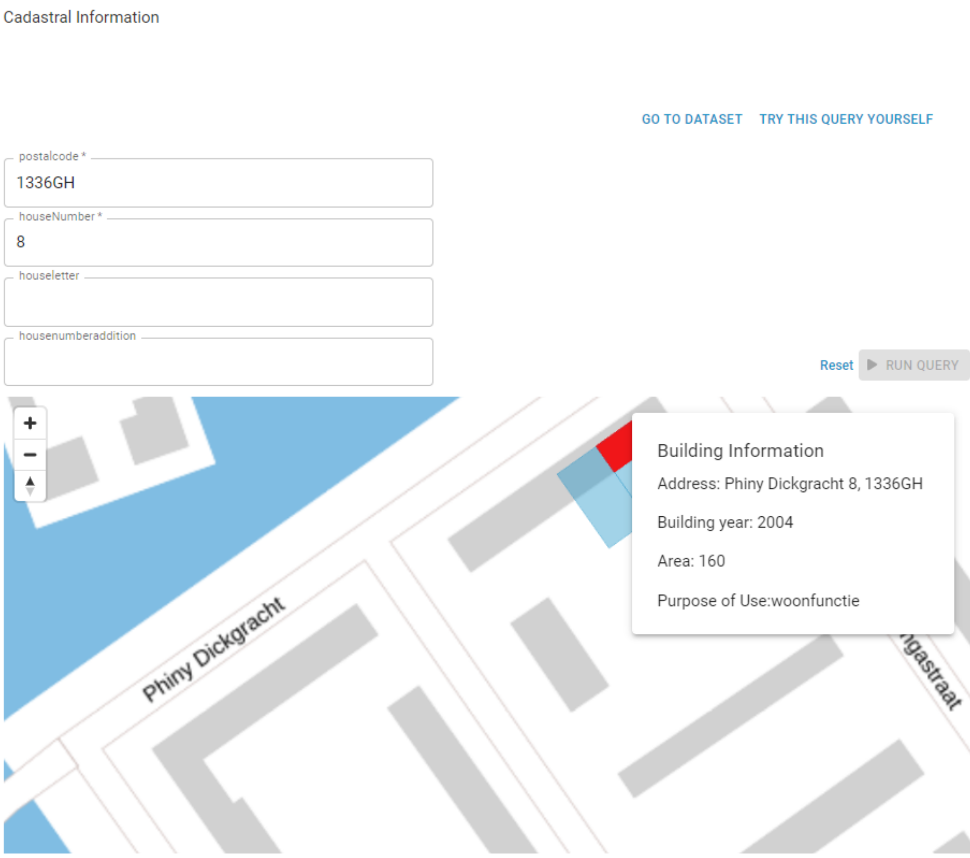


Figure 6.22: Result of query - Building information on a map

While developing the data stories, a limitation appeared that it was not possible to display the result of a query in more than one way. In the preliminary phase of a real estate transaction, it is desirable to display a parcel of land on a map and simultaneously visualize its surface area in a table. However, this cannot be achieved with a single query. Therefore, it is necessary to include two separate queries, one for displaying the information on a map and another for displaying information in a table. This does not appear to be an issue, but asking the user to indicate variables twice can reduce usability and cause ambiguity if the user accidentally types in two different variables, resulting in a difference in the outcome. Ideally, the parcels should be displayed on the map, and hovering over a parcel should immediately show its area in a table along with other relevant information. This could be a potential enhancement for Kadaster to add to the web environment.

The implementation with linked data has shown that the UML country profiles can be transformed into an OWL ontology model using Protégé, and that SPARQL construct queries need to be written to develop ontology-compliant datasets. It also turned out that an iteration of the attribute lists and the country profile had to be performed, as the country profile did not fully meet the country-specific needs of the Netherlands. The implementation with linked data has also shown that the data can be queried with SPARQL queries and that a prototype in the form of a data story can be developed in the web environment of the Kadaster Triple Store, displaying the retrieved data in a table or on a map, when geometry is available. The next chapter will discuss the assessment and evaluation of the prototype data stories.

7. Assessment and evaluation

This chapter discusses the assessment and evaluation of the developed data stories for the selected use cases. The data stories of real estate transaction and application of a building permit will be shown as prints in Sections 7.1 and 7.2, followed by an assessment based on metrics, and an evaluation which will be discussed in Section 7.3.

7.1. Data story of real estate transaction

The link to the data story cannot be shared publicly due to the inclusion of closed data. Therefore, the data story is attached as a print. Note that this printout of the data story for real estate transaction does not show that a user can enter a variable, as is the case in the working data story.

A Standards-based Portal for Integrated Land Administration Information - Real Estate Transaction

By LADM

DISCLAIMER: The data used to demonstrate a real estate transaction is entirely fake. No personally identifiable information is available in these datasets.

Project Background

Land administration requires access to data from various sources to fulfil various use cases. To support the retrieval of information for these use cases, it has been proposed that a portal be developed to integrate land administration information. The integration of this information is based on the implementation of the Land Administration Domain Model (ISO19152) as an ontology. The ontology is available here and the integrated dataset is available here. The development of the ontology was done as part of a student project with the TU Delft and continues as a research and development project.

One of the use cases for the development of a standards-based portal for integrated land administration information is to support the process followed when transacting real estate. In the Netherlands, several steps are included in this process and require the retrieval of information from multiple, distributed sources, both open data sources and closed or paid data sources. This is well regulated in the Netherlands and the relevant parties are already able to access and make use of the information in these sources.

An integrated data source improves the efficiency with which information can be accessed by users. Indeed, only two information points are now required from the user in the below demonstrator, the address and the bsn associated with a given building plan application. With this information, spatial plan, law restrictions, personal records, cadastral information and real estate value information can all be retrieved based on a number of easily defined SPARQL queries. Previously, this would have required access to several data sources, each with a complex model and different retrieval mechanisms.

This data story demonstrates the retrieval of data at different stages of the process flow. This is done by querying the information now integrated using the LADM ontology based on a set of questions which are relevant to users of the portal at various stages of the process flow.

Demonstrator Notes:

- The data available in this demonstrator only has the spatial scope of Almere and Zeewolde.
- To test the demonstrator, the following address information can be used as input:

Example 1:

- Name: Wilhelmina Kracht
- BSN: 99473114
- Address: Forum 63, 1315TG, Almere

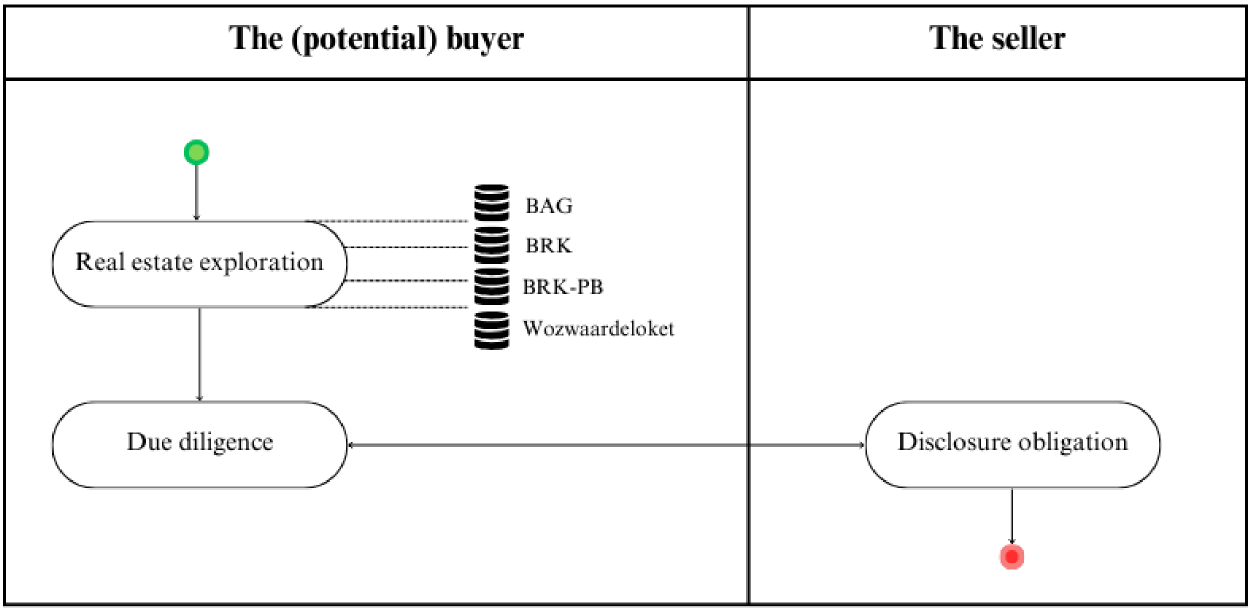
Example 2:

- Name: Evert Schults
- BSN: 3323109
- Address: Pluvierenweg 9, 3898LL, Zeewolde

1. Preliminary Phase

During the preliminary phase, an exploration of the real estate that is could be purchased is carried out by the potential buyer. There are several steps included as outlined in the following figure.

Figure 1. Real Estate Exploration



In this process flow, several data sources are accessed. Once all the information is retrieved by this seller, a due diligence on the property is carried out which includes the sharing of information between the potential buyer and seller of the property. Should the buyer then wish to continue with the transaction following the due diligence checks, the following stage of this flow is initiated. This is described in the subsequent sections of this data story.

Building Information

Upon initiation of a potential transaction, a real estate exploration process is carried out first on the building object. During this exploration, the following questions are posed:

- What is the purpose of use of the property?
- When was the property constructed?
- What is the surface area of the property?
- What are the current property valuations in the area?
- Are there any restrictions on the property?

The queries below uses the portal to answer these questions. In all cases, the address details are used as input parameters to the queries and the different information required during the exploration is returned to the user.

Technical Note: By clicking on the 'try this query yourself' button, it is possible to see the underlying query defined to support the answering of this question. This a SPARQL query; the native query language used to retrieve information from linked data sources. The query parameters defined for this SPARQL query, the address information, makes it possible for the user of the land administration portal to simply input address information and return this information in a table without having knowledge of SPARQL.

Forum 63, 1315TG, Almere	bijeenkomstfunctie	2004	100
Forum 63, 1315TG, Almere	bijeenkomstfunctie	2004	100
Forum 63, 1315TG, Almere	gezondheidszorgfunctie	2004	100
Forum 63, 1315TG, Almere	gezondheidszorgfunctie	2004	100
Forum 63, 1315TG, Almere	industriefunctie	2004	100

The following query visualises the same results as the above query but on a map interface. By clicking on the geometry shown, it is possible to see the specific spatial plan document associated with this geometry.

Parcel Information

Following the investigation of the building, the cadastral information related to parcels are then retrieved. The following questions are posed:

- What is the surface area of the parcel the property is located on?
- What restrictions are associated with the parcel?

Forum 63, 1315TG, Almere	20
Forum 63, 1315TG, Almere	22
Forum 63, 1315TG, Almere	2.392
Forum 63, 1315TG, Almere	296
Forum 63, 1315TG, Almere	311

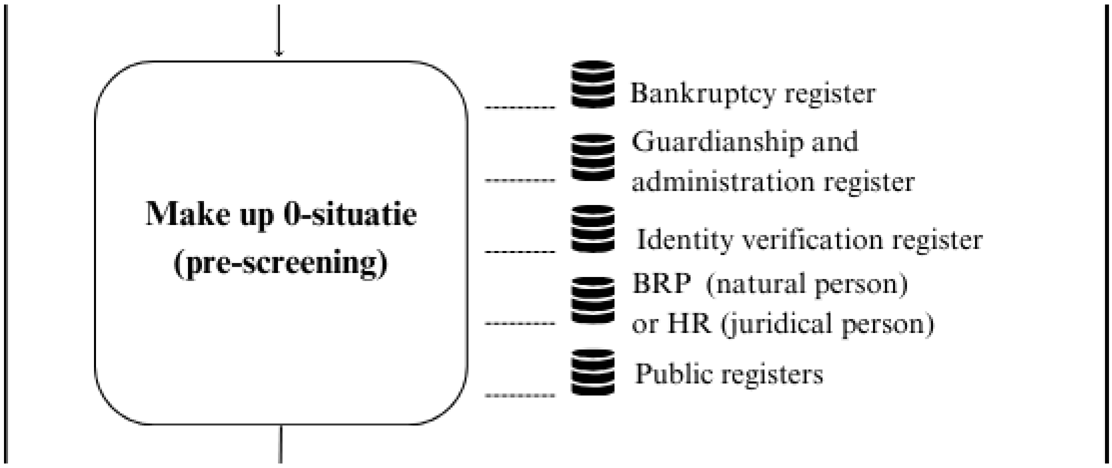
The following query visualises the same results as the above query but on a map interface. By clicking on the geometry shown, it is possible to see the specific spatial plan document associated with this geometry.

2. Sequential Phase

Following the initiation of a real estate transaction, the preparation of a sales agreement is initiated. Following the signing of these documents by all parties, the prescreening of the individuals for financial information is initiated. A large part of this process is not demonstrated in this data story. What is interesting to demonstrate as part of this pre-screening for a transaction is the investigation into the current registered ownership and the existence of any mortgages on the property that is being transacted.

This checking of current registration is done based on access to the BRP and BRK datasets and is required before a notarial deed can be signed. Following the check, both parties sign the deed and the final transaction is completed. The following figure illustrates the final part of the the transaction process.

Figure 2. Pre-Screening Notarial Information



Personal Information and Ownership

In order to carry out the personal information, ownership and final financial check, the following questions are posed to the integrated land administration portal:

- What is the identity of the registered owner?
- What are the person's name, address details, and civil status, and is this information complete?
- Who is the current owner of the real estate being transacted?

To answer these questions, the address information of both the seller and buyer are used as input as well as the address of the real estate being transacted. The following queries demonstrate how these checks can be carried out using the integrated land portal.

Completeness of Personal Information

35.185.787	Ilse	Berkelmans	gehuwd
27.976.889	Irene	Hes	gehuwd
101.784.344	Lara	van Vessem	gehuwd
45.531.654	Kevin	Rosbergen	gehuwd
54.353.379	Lars	Boerma	gehuwd

Current Ownership of Real Estate

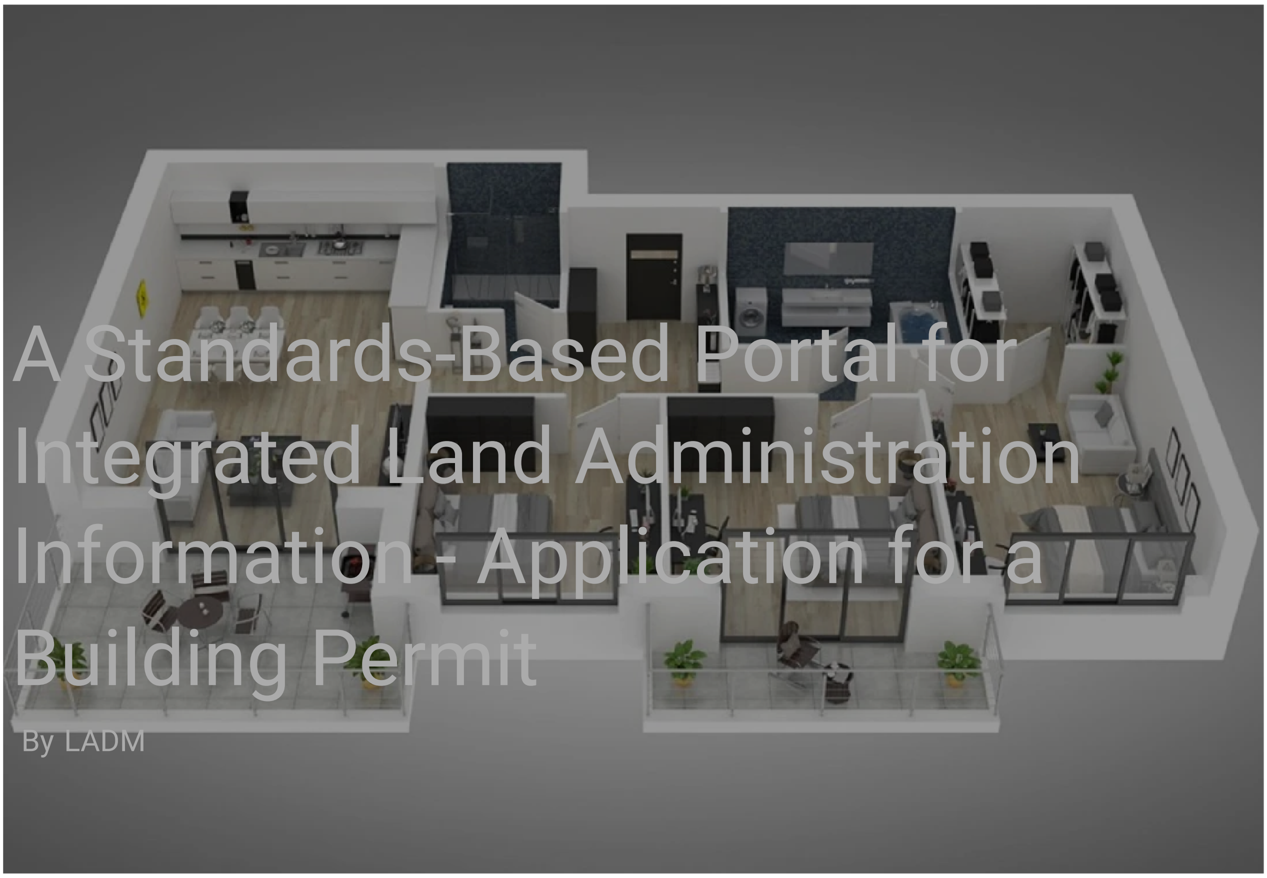
Samoastraat 18, 1339PG, Almere	89.871.410	Grietje	Kant	gehuwd
Samoastraat 16, 1339PG, Almere	89.871.410	Grietje	Kant	gehuwd
Samoastraat 14, 1339PG, Almere	89.871.410	Grietje	Kant	gehuwd
Willem Bontekoestraat 95, 1335NE, Almere	117.175.452	Floor	Fortuin	gehuwd
Willem Bontekoestraat 93, 1335NE, Almere	117.175.452	Floor	Fortuin	gehuwd

Source datasets:

- Integrated Portal for Land Administration

7.2. Data story of application for a building permit

The link to the data story cannot be shared publicly due to the inclusion of closed data. Therefore, the data story is attached as a print. Note that this printout of the data story for a building permit does not show that a user can enter a variable, as is the case in the working data story.



A Standards-Based Portal for Integrated Land Administration Information - Application for a Building Permit

By LADM

DISCLAIMER: The data used to demonstrate a building permit application is entirely fake. No personally identifiable information is available in these datasets.

Project Background

Land administration requires access to data from various sources to fulfil various use cases. To support the retrieval of information for these use cases, it has been proposed that a portal be developed to integrate land administration information. The integration of this information is based on the implementation of the Land Administration Domain Model (ISO19152) as an ontology. The ontology is available here and the integrated dataset is available here. The development of the ontology was done as part of a student project with the TU Delft and continues as a research and development project.

One of the use cases for the development of a standards-based portal for integrated land administration information is the application of a building permit. In the Netherlands, several steps are included in this process and require the retrieval of information from multiple, distributed sources, both open data sources and closed or paid data sources. This is well regulated in the Netherlands and the relevant parties are already able to access and make use of the information in these sources. An integrated data source improves the efficiency with which information can be accessed by users. Indeed, only two information points are now required from the user in the below demonstrator, the address and the bsn associated with a given building plan application. With this information, spatial plan, law restrictions, personal records and cadastral information can all be retrieved based on a number of easily defined SPARQL queries. Previously, this would have required access to several data sources, each with a complex model and different retrieval mechanisms.

This data story demonstrates the retrieval of data at different stages of the process flow. This is done by querying the information now integrated using the LADM ontology based on a set of questions which are relevant to users of the portal at various stages of the process flow.

Demonstrator Notes:

- The data available in this demonstrator only has the spatial scope of Almere and Zeewolde.
- To test the demonstrator, the following address information can be used as input:

Example 1:

- Name: Wilhelmina Kracht
- BSN: 99473114
- Address: Forum 63, 1315TG, Almere

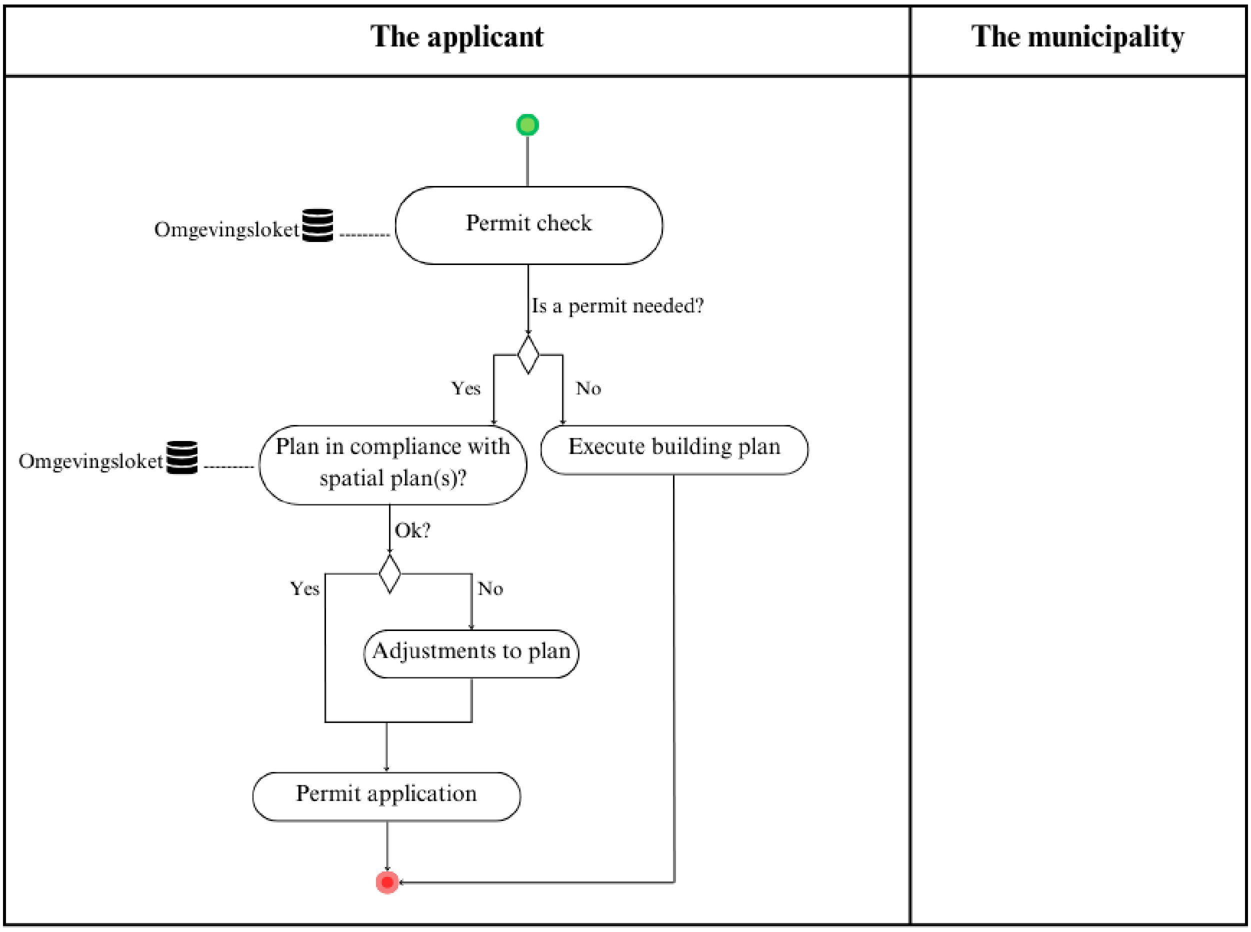
Example 2:

- Name: Evert Schults
- BSN: 3323109
- Address: Pluvierenweg 9, 3898LL, Zeewolde

1. Preliminary Phase

During the preliminary phase, a building plan is submitted and this initiates a building permit application. There are several steps to this application as outlined in the following figure.

Figure 1. Building permit application



In this process flow, only one source of information is required, namely; the Spatial Plans dataset for the Netherlands. Here, the building plan submitted by the applicant is checked against the spatial plans for a given location to assess whether the building plan is under the spatial plan. If not, a building permit needs to be requested. If a permit is requested, this initiates the subsequent phase described in this story.

Spatial Plan Information

The first step in this process flow is not demonstrated here, it is simply assumed for demonstration purposes that a permit is required. Upon notification that a building permit is, indeed, required, the compliance of the building plan to the spatial plan is checked. The following question is asked:

- What spatial plan(s) are attached to the specific address associated with a building plan?

The queries below uses the portal to answer this question. In the first query, the results of the query is returned as a table and in the second query, these results of placed on a map. The input parameters allow the user of this portal to simply fill in the address information associated with a building plan and, when executed, retrieve a (list of) spatial plan(s) associated with this address.

Technical Note: By clicking on the 'try this query yourself' button, it is possible to see the underlying query defined to support the answering of this question. This a SPARQL query; the native query language used to retrieve information from linked data sources. The query parameters defined for this SPARQL query, the address information, makes it possible for the user of the land administration portal to simply input address information and return this information in a table without having knowledge of SPARQL.

Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 8, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 12, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Kemphaanweg 1, 1358AA, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-

The following query visualises the same results as the above query but on a map interface. By clicking on the geometry shown, it is possible to see the specific spatial plan document associated with this geometry.

Following the identification of a spatial plan and retrieving this information, the applicant of the building permit needs to assess the information in the spatial plan to answer the following question:

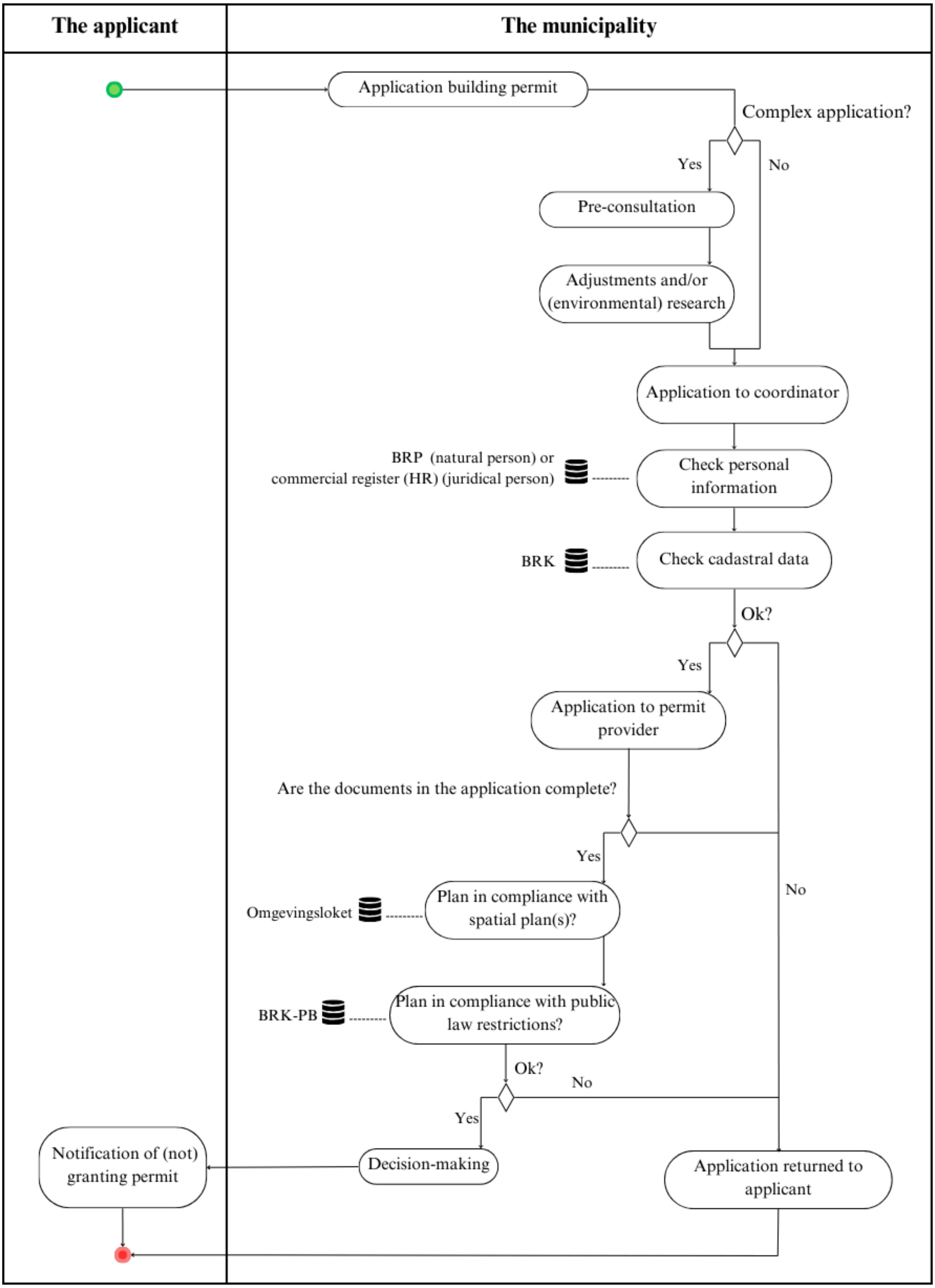
- Is the building plan in compliance with the spatial plan(s)?

This cannot be done based on a simple SPARQL query because it requires specialist knowledge and is not demonstrated here. The information required to carry out this assessment, however, is included in the results of the previous queries. If the plans need to be adjusted, this is done by the applicant and then the building plan is submitted to the municipality. This concludes the preliminary phase of this process flow.

2. Sequential Phase

Following the submission of the building permit in the previous phase, a sequential phase is then followed. This process flow is illustrated in the following figure.

Figure 2. Building permit assessment



This process flow is slightly more complex and involves the querying of several distributed datasets. Following the submission of the building permit by the application, a municipality official will assess whether the application is complex. Assuming for the sake of this demonstration that the application is not complex, the application proceeds to a coordinator. Here, the coordinator will check with Key Register of Persons (Basisregistratie Personen) for the personal information of the applicant. If the personal information of the applicant for the building permit matches the personal information associated with the ownership of the building to which the plan applies as registered in the Key Register Cadastre (Basisregistratie Kadaster), the application will be moved to the permit provider.

The permit provider will perform another check for compliance against the relevant spatial plans. For this, the same spatial plans dataset will be used to check this information. If the building plan is in compliance, the permit provider will then also check whether the building plan complies with the public law restrictions (if any) associated with the address. To check this compliance, the permit provider also needs access to the Public Law Restrictions dataset. Once the application has passed all these compliance check, the positive result will be returned to the applicant.

Personal Information

The first step at which information needs to be retrieved from the portal is to check for personal information. To retrieve the relevant information required for this step, the following question is posed:

- Is the personal information on the application in line with the information in the key register of persons?

To answer this question, a municipality official needs to enter the bsn defined in the building permit application and retrieve the personal information associated with this bsn number. The following query returns personal information. The input parameter allows the user to query personal information for a defined bsn number.

35.185.787	Ilse	Berkelmans	V

The results of this query then need to be checked against the personal information associated with a given address as registered in the Key Register Cadastre. For this, the person(s) defined as owners of a given building or parcel should be queried. To do so, the following question should be defined as a query:

- Which person is registered as owning a given building, apartment and/or parcel?

This can be answered by the portal in two ways, the first is based on the input of an address as noted in the building plan application and checking for a match in BSN or by inputting the BSN number associated with the building plan and checking if the address matches that noted on the building plan. Both options are implemented in the queries below.

Pluvierenweg 9-257, 3898LL	3.323.109	Evert	Schults
Pluvierenweg 9-582, 3898LL	12.789.580	Merle	Goedegebuure
Slingerweg 1-655, 3896LD	87.430.153	Hilde	van Ginneken
Slingerweg 1-656, 3896LD	87.430.153	Hilde	van Ginneken
Pluvierenweg 9-556, 3898LL	93.258.788	Emma	Carlier

Building Information

Once the personal information has been verified, the spatial plan information and information about public law restrictions should be checked. In order to check this, the following questions are posed:

- What cadastral information is available for the address to which the building plan is associated?
- What spatial plans are applicable to the address of the proposed building plan?
- What spatial area does a spatial plan attached to a specific address apply to?
- What public law restrictions are applicable to the address of the proposed building plan?

The first query simply looks for all the cadastral data associated with a given address including the age and location of the building, the parcel on which the building is located and the size of each of these. The second query is a duplicate of the query used by the applicant in the preliminary phase. Here, the address information associated with a building plan is used as an input parameter to identify the spatial plans and then placed on a map. The last query is also defined based on the available address information and any available law restrictions are returned.

Cadastral Information

Spatial Plans

Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 8, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 12, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Kemphaanweg 1, 1358AA, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-

Public Law Restrictions

If no results are returned in the following query, no public law restrictions apply to a given address.

Zandzuigerstraat 61, 1333MX, Almere	Opiumwet: Sluiting object	2020-08-20
Zandzuigerstraat 61, 1333MX, Almere	Opiumwet: Sluiting object	2020-11-23
Zandzuigerstraat 63, 1333MX, Almere	Opiumwet: Sluiting object	2020-08-20
Zandzuigerstraat 63, 1333MX, Almere	Opiumwet: Sluiting object	2020-11-23
Zandzuigerstraat 65, 1333MX, Almere	Opiumwet: Sluiting object	2020-08-20

Source datasets:

- Integrated Portal for Land Administration

7.3. Assessment

This section describes the assessment of the data stories using various metrics, and discusses the usability test conducted to evaluate the usability of the prototype, as described in Section 7.3.1.

Ontology evaluation can be defined as the process of deciding on the quality of an ontology and its implementation in terms of certain metrics [Hlomani and Stacey, 2014]. By implementing the ontology with data and evaluating the resulting data story, there is a possibility of evaluation that aims to assess the impact and effectiveness of the ontology in a real world context. This includes examining how well the ontology models the data, how well the data story communicates with stakeholders, and how well the ontology and data story meet the needs of the use cases.

The first level of difficulty is to decide on the relevant assessment criteria. To solve this problem, an approach has been proposed: induction, by empirical testing of ontologies to identify desirable properties of ontologies in the context of an application. Context is important in choosing the right metrics. Nevertheless, there will be subjectivity in the choice of criteria, as it has been largely the responsibility of the evaluator to determine the metrics to be used in assessment [Hlomani and Stacey, 2014]. This is also observed in the context of this study. However, there are examples identifying assessment metrics for assessing data in querying in the same manner as in this study [Yusof, 2023] [Jonker, 2023]. Based on this previous work and the objective of this study to determine the benefits and drawbacks of implementing LADM for data dissemination in the Netherlands, the following metrics have been established, as presented in Table 7.1.

Metric cluster	*Metric*	*Description*
Performance metrics	Time efficiency	Measuring the time it takes to answer a set of questions at a particular phase of the use case.
	Resource efficiency	Measuring the resources required to answer a set of questions at a particular phase of the use case.
Data quality metrics	Data accuracy	Measuring the level of correctness and precision of data returned.
	Completeness	Evaluating how well the use case captures all the relevant data and information.
User experience metrics	Usability	Evaluating the ease of use and intuitiveness of the system.
	Accessibility	Evaluating if the prototype is accessible to all types of users.
Resource metric	Resource optimization	Evaluating if there is optimal use of resources.
Scalability metrics	Scalability	Evaluating whether the prototype can handle an increasing volume of data without a significant decrease in performance.
	Reusability	Evaluating whether other domain experts can easily (re)use the model for related applications.

Table 7.1: Assessment metrics

Note that the metrics are not ranked in order of importance. However, it is reasonable to assume that the data quality metrics, to ensure the reliability of the data, the user experience metrics, to determine whether people perceive the prototype as user friendly and accessible, and the performance metrics to ensure good performance are among the more important. This prototype is a web environment that interacts with people, so no matter how well the prototype works, if people do not want to interact with it, it will be of no value. As for accuracy, even if all other metrics are rated as highly ass possible, the prototype still cannot be used in practice because it disseminates (partly) inaccurate information and thus cannot guarantee reliability.

Figure 7.1 and 7.2 present the metric assessment of the current state of the use cases and the use cases with the implementation of LADM based on the selected use cases.

		Current state of the use cases		*Use cases with LADM implementation*	
Metric	*Assessment*	*Real estate transaction: Preliminary stage*	*Real estate transaction: Sequential stage*	*Real estate transaction: Preliminary stage*	*Real estate transaction: Sequential stage*
Time efficiency	How long does it take to obtain data?	15-20 minutes.	11 minutes + 8 minutes + 8 minutes = 27 minutes (Beroepsorganisatie, (2023))	2-5 minutes.	2-5 + 2-5 + 2-5 = 6-15 minutes.
Resource efficiency	How many resources must be consulted to obtain the data?	BAG, BRK, BRK-PB and Wozwaardeloket.	Bankruptcy register, Guardianship and Administration register, VIS, BRP or the commercial register and BRK.	The prototype / data story.	The prototype / data story and Bankruptcy register, Guardianship and Administration register and VIS.
Data accuracy	How accurate is the data obtained?	As accurate as possible, as the data in these resources is taken from the base registers and updated accordingly.		As accurate as possible, as the data in these resources is taken from the base registers and updated accordingly. The WOZ and BRP data are fake data.	
Completeness	How complete is the data obtained?	A person can search for or request any information they wish. However, one may get a lot of unrequested data as well.		Someone can currently only retrieve the information defined in the construct queries, from the municipality 'Zeewolde'	Someone can currently only retrieve the information defined in the queries from the BRP and BRK, from the municipality 'Zeewolde'.
Usability	How easy is it to obtain the data?	Someone needs some understanding which geoportal is needed to retrieve certain information. The way in which data can be retrieved differs from one environment to another; this also requires attention.		Within the prototype, a person only needs to scroll to where the right information can be accessed by simply typing in address information as a variable.	
Accessibility	Are there any obstacles to retrieving data?	Information from the BRK must be requested before it can be viewed. Wozwaardeloket has a maximum number of requests.		One must enter address information as a variable multiple times as it is not possible to show a table and map at the same time.	No obstacles in the prototype. Nevertheless the Bankruptcy register, Guardianship and Administration register, VIS still need to be consulted.
Resource optimization	How efficiently are resources being used?	In the BAG and Wozwaardeloket, it is not possible to obtain selected information for a whole selection of buildings. The result is more information about a building than requested, and a need to click multiple times on individual buildings to obtain information for a collection of buildings.		The provided information is limited to what is necessary to answer the questions.	The data resources available are inadequate to answer all questions because the ontology does not include all registers.
Scalability	How well can it be scaled, and how good will performance be when the number of users or activities increases?	These are all individual registers / geoportals, that manage their own datasets. It is expected that there will be no difference in performance when scaling happens.		In theory scalability is unlimited as every possible register could be included. But research need to be done to determine applicability. Performance will need to be evaluated as scaling occurs, the expectation is that there will be no difference in performance, as demonstrated by data stories of KKG.	
Reusability	How well are the resources able to be re-used in other contexts?	All resources are able to be reused in other contexts.		In other contexts, one may want to retrieve different data. This will require the creation of different query constructs, which need to be constructed. The prototype itself is suitable for reusability as other domains of data could be incorporated in the ontology.	

Figure 7.1: Assessment of metrics - real estate transaction

		Current state of the use cases		*Use cases with LADM implementation*	
Metric	*Assessment*	*Building permit: Preliminary stage*	*Building permit: Sequential stage*	*Building permit: Preliminary stage*	*Building permit: Sequential stage*
Time efficiency	How long does it take to obtain data?	2-5 minutes.	15-20 minutes.	2-5 minutes.	5-10 minutes.
Resource efficiency	How many resources must be consulted to obtain the data?	Spatial plans (Omgevingsloket.nl).	BRP or commercial register, BRK-PB and spatial plans (Omgevingsloket.nl).	The prototype / data story.	
Data accuracy	How accurate is the data obtained?	As accurate as possible, as the data in these resources is taken from the base registers and updated accordingly.		As accurate as possible, as the data in these resources is taken from the base registers and updated accordingly. The BRP data is fake data.	
Completeness	How complete is the data obtained?	A person can search for or request any information they wish. However, one may get a lot of unrequested data as well.		Someone can currently only retrieve the information defined in the construct queries, from the municipality 'Zeewolde'.	Someone can currently only retrieve the information defined in the construct queries, from the municipality 'Zeewolde'. Also no information from the commercial register can be retrieved, only from BRP, in the case of a natural person.
Usability	How easy is it to obtain the data?	Relatively easy, since one only need to consult one geoportal that is visually comprehensible.	Someone needs some understanding which geoportal is needed to retrieve certain information, and how this geoportal communicates information.	Within the prototype, a person only needs to scroll to where the right information can be accessed by simply typing in address information.	
Accessibility	Are there any obstacles to retrieving data?	No obstacles experienced.	Information from the BRK must be requested before it can be viewed.	One must enter address information as a variable multiple times as it is not possible to show a table and map at the same time.	
Resource optimization	How efficiently are resources being used?	Quite efficient, as it is visualised on a map, along with various tabs such as rules and explanations.	It is not possible to obtain selected information from the register, so the result is, alongside the requested information, unnecessary information.	The provided information is limited to what is necessary to answer the questions.	The data resources available are inadequate to answer all questions because the ontology does not include all registers.
Scalability	How well can it be scaled, and how good will performance be when the number of users or activities increases?	These are all individual registers / geoportals, that manage their own datasets. It is expected that there will be no difference in performance when scaling happens.		In theory scalability is unlimited as every possible register could be included. But research need to be done to determine applicability. Performance will need to be evaluated as scaling occurs, the expectation is that there will be no difference in performance, as demonstrated by data stories of KKG.	
Reusability	How well are the resources able to be re-used in other contexts?	All resources are able to be reused in other contexts.		In other contexts, one may want to retrieve different data. This will require the creation of different query constructs, which need to be constructed. The prototype itself is suitable for reusability as other domains of data could be incorporated in the ontology.	

Figure 7.2: Assessment of metrics - building permit

Evaluating the assessment, several observations can be made regarding the various metrics, as detailed below.

Time efficiency The estimated time assessment shows that the developed prototype saves time in obtaining data. During the preliminary stage of a real estate transaction, there is an average time saving of 15 minutes, and in the sequential stage, the time saving is on average 16.5 minutes. In the use case of a building permit, time is only saved in the sequential stage, with an average of 10 minutes saved.

Resource efficiency The registers that must be consulted in the current state of the use cases and are also included in the ontology are replaced by the data story. This results in only one resource needed to be consulted, in three out of four cases, with the LADM implementation. However, the ontology does not include certain registers, such as the bankruptcy register, the guardianship and administration register, and the VIS. Therefore, it is necessary to consult these registers separately in order to retrieve the required data. This is the case for the sequential phase in the real estate transaction.

Data accuracy In both situations, the data is extracted from the Dutch registers, ensuring maximum accuracy. However, the ontology data requires manual updates. As long as these updates are done regularly, there is no difference in the data compared to the data in the registers. However, the prototype will always lag behind the official registers. It is important to note that the WOZ and BRP data in the data story is fake due to privacy laws and Kadaster not owning the WOZ data, thus this data not being accurate.

Completeness Currently, users are able to search for or request any data they require, this search may also return unwanted data. For instance, if a user only requires the construction year of a building, they may also receive information on its status and area. Also, users are unable to request specific data types, such as construction year, for multiple buildings simultaneously. To access this information, one must click on individual buildings multiple times and search for its construction year. The prototype allows for searching specific information for multiple buildings simultaneously. However, it is not possible to search for data that is not included in the queries. Moreover, the queried data is limited to the data included in the ontology, excluding data from the HR, bankruptcy register, guardianship and administration register, and VIS. It is also important to note that only data related to the municipality of 'Zeewolde' can be queried due to the unavailability of data in linked data form for the whole of the Netherlands.

Usability There is currently a need to understand which register to consult in order to retrieve specific data, as well as how to extract information from this geoportal. Within the prototype, a person can scroll to the desired query and access data by entering address information or personal information as a variable.

Accessibility Currently, to obtain information from the BRK, a request must be made for a small fee in the case that someone is not the entitled party. One potential inconvenience for users of the prototype is the need to repeatedly enter a variable value to retrieve data displayed in multiple ways. As query results cannot be displayed simultaneously in both a table and on a map.

Resource optimization Resource optimization differs among geoportals. The Omgevingsloket geoportal provides a clear combination of map information and structured information tabs. In contrast, other geoportals do not offer the option to query specific information and provide the user with a set of data that also includes unsolicited information. The prototype only provides the necessary information stated in the use cases. However, this also means that the prototype is not able to answer all questions in the use cases as it can only query registers included in the ontology.

Scalability Currently, registers and geoportals manage their own data, and it is expected that performance will remain consistent when scaling occurs. The prototype is theoretically infinitely scalable, as every other register can be included as long as there is a corresponding class in the ontology. Performance needs to be evaluated when scaling occurs, but it is expected that there will be no major differences, as demonstrated by the data stories of the KKG created by Kadaster, where larger amounts of data are already being processed.

Reusability Data from individual registers can be reused in other contexts as they provide a wide range of applicable data. Retrieving a wide range of data from the prototype requires different queries to be written. Therefore, the prototype has the potential to be reusable, but actions need to be taken to make this possible.

Figure 7.3 visualizes the assessment of these metrics. This figure shows which state of the use case, current state or LADM implementation, provides more value when looking at a single metric and its assessment. Blue metrics are measurable and approached more objectively, while green metrics are less or not measurable and approached more subjectively.

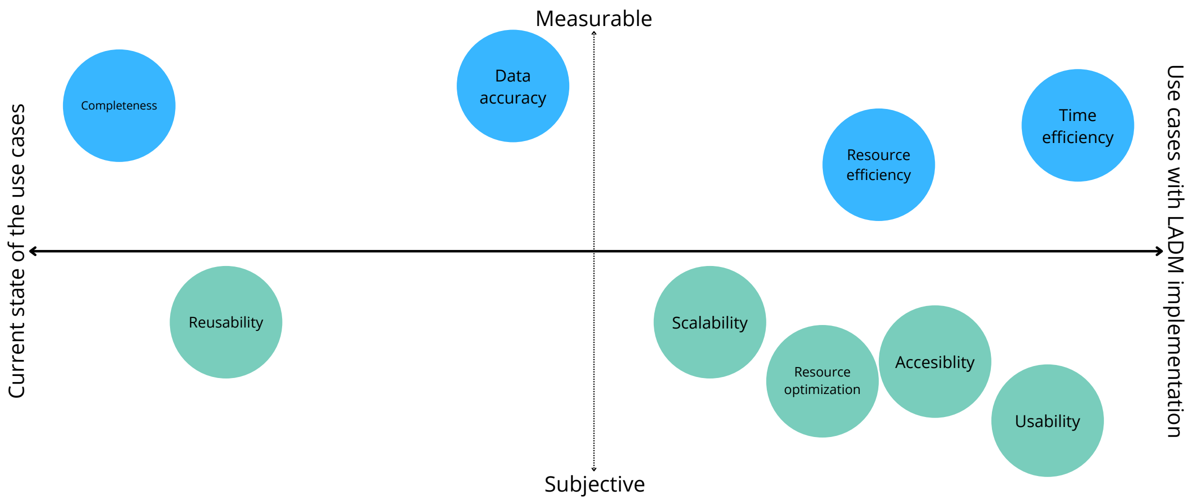


Figure 7.3: Visualization metric assessment

As previously stated, these metrics do not have a specific order of priority, but some are logically more important than others. Also it is important to consider that the assessment is based on the resulting prototype and not its potential. Therefore, this visualization does not serve as a basis to draw a final conclusion upon whether implementing LADM is more beneficial for data dissemination than the current approach of the use cases. Its purpose is to provide insights into the benefits and drawbacks of implementing LADM Edition II in the Netherlands for data dissemination. Developments of the prototype can affect the assessment. For example, the completeness of the ontology could be improved by including more datasets and making more queries. However, usability may be affected by an increase in the number of queries, as currently it is easy to find the desired query due to the limited number of queries included.

As visualized in Figure 7.3, the usability metric is the most subjective metric to assess. In order to have a more comprehensive understanding of the usability, a test was carried out which will be discussed in the next section.

7.3.1. Usability test

A usability test was conducted to evaluate the usability of the prototype portal. Due to time constraints in optimizing the prototype for both identified use cases, it was decided to conduct the usability test focusing solely on the use case of a building permit as the prototype was sufficiently optimized. This decision was made to ensure that the usability test could be conducted effectively within the available resources and time frame.

Usability is the extent to which a product can be used to achieve a specific goal in a specific context with effectiveness, efficiency, and satisfaction, according to ISO 9241-11 [ISO, 2010]. Effectiveness is about the accuracy and completeness with which users can achieve specified goals. Efficiency is about the resources expended in relation to the accuracy and completeness with which users can achieve specified goals. Satisfaction is about the comfort and acceptability of use [Mifsud, 2019]. The level of usability is also determined by the presence of frustration. The absence of frustration while using something is what makes it usable [Rubin and Chisnell, 2008].

Usability testing is a method which enables to test the functionality of a product, in this case the prototype in the form of a data story. Usability testing includes people as test users who are a representation of the user groups for which the prototype is intended. Previous research has shown that five users are enough to identify about 80% of the potential issues of a prototype [Nielsen, 2000]. Even so, according to this research, no more than 15 test users are needed to identify 100% of the potential issues within a prototype. The test users for this usability test are subdivided into groups according to being a non-professional (people that do not have experience with and/or knowledge of land administration systems) or a professional (people that do have experience with and/or knowledge of land administration systems). A distinction has also been made between student and non-student because it is less likely that a student will apply for a building permit given students usually do not own a home. Students are therefore less representative of the target group of this prototype. However, testing with students can still provide valuable insights.

Defining the objective of the usability test is also necessary. The overall goal is to assess the usability of the prototype. This usability will be tested by more detailed goals, including:

- The prototype should guide the user in retrieving information efficiently.
- The prototype should provide information that is clear to the user.

- The prototype should be easy to use and/or there should be a learning curve.
- The prototype must give the user certainty about the information retrieved.
- The prototype should not create limitations and/or frustration for the user.

Development of the usability test
The next step is to create the usability test. The purpose of the test is to guide the test users through the test with clear explanations, to present the tasks to be performed, and to collect information about the usability through the users' answers. The usability test was created as a Dutch-language questionnaire using Google Forms, as the test users are native Dutch speakers and the prototype is designed for the Dutch context. The prototype was translated into Dutch for the usability test to ensure that language does not influence the test results. The translated data story for the usability test can be found in Appendix E. The usability test is carried out on two separate computers. One computer presents the web environment of the data story where the tasks are to be performed, while the other computer presents the Google Forms for filling in the questionnaire.

The usability test starts with a description of the context and aim of the test, and a question to identify the user group the test user represents. Following, there are eight sections in which the test user is asked to perform a task, give opinion, and rate their experience with the prototype. The test concludes with a section in which the user is asked to rate their overall experience with the prototype, and to provide general feedback or comments. The detailed content of the questionnaire will be discussed below.

The usability test starts with a general explanation of the context and the usability test, see Figure 7.4:

> *This user test is part of a graduation project for the Master Geomatics.*
> Welcome to this user test evaluating the usability of a prototype portal for retrieving land administration information. Land administration information includes data and documents used to record, manage and update land ownership. This includes information on exact boundaries, property rights, legal documents such as title deeds, tax information and topographical data.
>
> In this user test, you adopt the identity of a fictional person. In one case, this means you are a person who wants to make a change to her home. This person is interested in, for example, spatial plans and restrictions attached to their home. In the other case, you are someone working at the municipality who receives and processes the application for a building permit.
>
> This user test will consist of 8 different parts. For each part, a description is given about the context, after which a task to be performed is described. After this, you will be asked to give your opinion on the usability of the prototype in relation to the task performed, and you will be asked to give a grade on the usability by agreeing or disagreeing with statements.

At the end of the test, some general questions are asked regarding the prototype's usability, and there is the opportunity to give general comments.

I will time how long it takes to perform the tasks. However, it is not necessary to complete the tasks as quickly as possible.

Aanvraag van een bouwvergunning

Deze gebruikerstest is onderdeel is van een afstudeerproject voor de Master Geomatics.

Welkom bij deze gebruikerstest waarbij het gebruiksgemak van een prototype portaal voor het opvragen van land administratie informatie wordt getest. Land administratie informatie omvat gegevens en documenten die worden gebruikt om landeigendom vast te leggen, te beheren en bij te houden. Dit omvat onder andere informatie over de exacte grenzen, eigendomsrechten, juridische documenten zoals eigendomsaktes, belastinginformatie en topografische gegevens.

In deze gebruikerstest neemt u de identiteit aan van een fictief persoon. In het ene geval betekent dit dat u een persoon bent die een verandering wilt uitvoeren aan haar woning. Hiervoor is deze persoon geïnteresseerd in bijvoorbeeld ruimtelijke plannen en beperkingen die vast zitten aan zijn woning. In het andere geval bent u iemand die bij de gemeente werkt die de aanvraag voor een bouwvergunning ontvangt en verwerkt.

Deze gebruikerstest zal uit 8 verschillende onderdelen bestaan. Per onderdeel wordt er allereerst een omschrijving gegeven, waarnaar er een taak wordt omschreven die uitgevoerd moet worden. Hierna wordt uw mening gevraagd over het gebruiksgemak van het prototype in relatie tot de taak, en wordt gevraagd een cijfer te geven over het gebruiksgemak aan de hand van vragen.

Aan het einde van de test worden nog een paar algemene vragen gesteld met betrekking tot het gebruiksgemak van het prototype en is er ruimte voor algemene opmerkingen.

Ik zal de duur van het uitvoeren van de taken timen, het uitvoeren van de taken hoeft echter niet zo snel mogelijk.

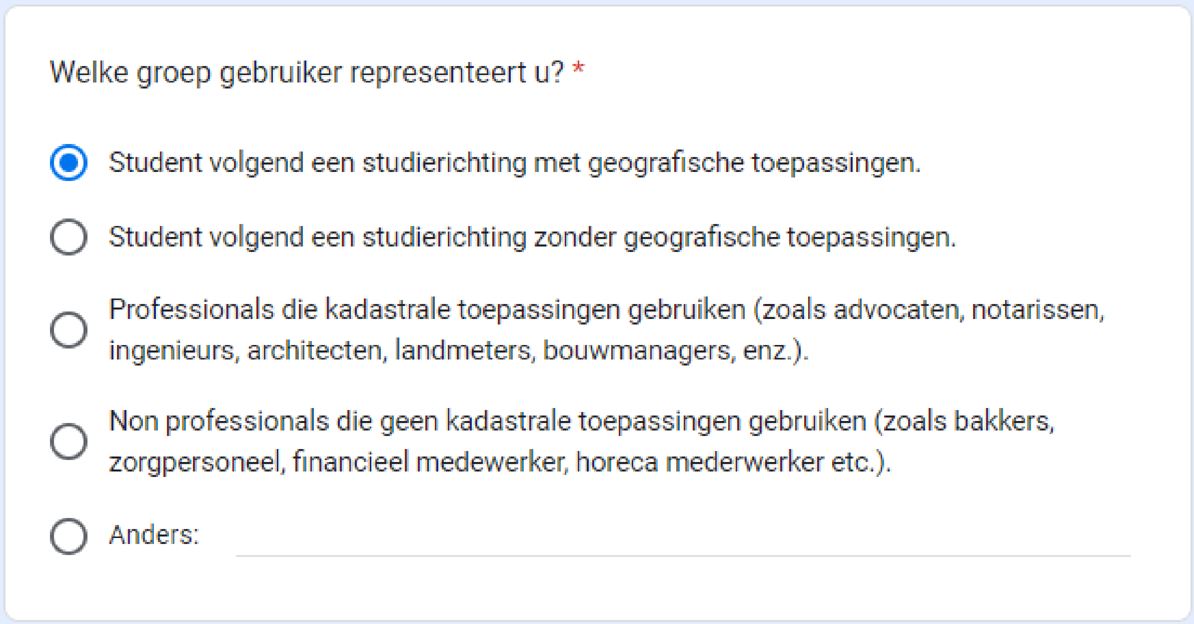
Figure 7.4: General explanation of the context and the usability test

The general description at the beginning of the questionnaire is followed by a question to determine which user group the test user represents, see Figure 7.5:

Which user group do you represent?

- Student following a study programme with geographical applications.
- Student following a study programme without geographical applications.
- Professionals using cadastral applications (such as lawyers, notaries, engineers, architects, surveyors, construction managers, etc.).

- Non-professionals not using cadastral applications (such as bakers, health workers, financial workers, hotel workers, etc.).
- Other:


Welke groep gebruiker representeert u? *

- Student volgend een studierichting met geografische toepassingen.
- Student volgend een studierichting zonder geografische toepassingen.
- Professionals die kadastrale toepassingen gebruiken (zoals advocaten, notarissen, ingenieurs, architecten, landmeters, bouwmanagers, enz.).
- Non professionals die geen kadastrale toepassingen gebruiken (zoals bakkers, zorgpersoneel, financieel medewerker, horeca mederwerker etc.).
- Anders:

Figure 7.5: User group representation

The usability test consists of eight sections. Each section contains a brief description that provides context to the test user, a task description, three questions about the user's opinion on task execution, and four statements about task execution that the user must rate to indicate their level of agreement. The following sections will provide more detailed information on these eight sections.

A brief description at the beginning of each section describes that the test user will adopt the identity of a fictional person. The two different identities are regarding a Dutch woman named Wilhelmina and a person working at the municipality processing applications for a building permit.

Regarding the identity of Wilhelmina, the description is as follows, see Figure 7.6:

> To perform the following task, you will adopt the identity of Wilhelmina Kracht. Wilhelmina is a Dutch woman with the following personal details: (disclaimer: this is fake personal data)
>
> Personal data
> First name: Wilhelmina
> Surname: Kracht
> Citizen Service Number (BSN): 99473114
> Gender: Female

> Address details to which the building plan relates
> Street: Forum
> House number: 63
> Postal code: 1315 TG
> City: Almere

Regarding the identity of someone working at the municipality, the description is as follows, see Figure 7.7:

> To perform the following task, you will adopt the identity of someone working at the municipality processing applications for a building permit. You receive the application for a building permit from Wilhelmina, the application includes the following information: (disclaimer: this is fake personal data)
>
> Personal data
> First name: Wilhelmina
> Surname: Kracht
> Citizen Service Number (BSN): 99473114
> Gender: Female
>
> Address details to which the building plan relates
> Street: Forum
> House number: 63
> Postal code: 1315 TG
> City: Almere

Voor het uitvoeren van de volgende taak neem je de identiteit aan van Wilhelmina Kracht. Wilhelmina is een Nederlandse vrouw met de volgende persoonlijke gegevens (disclaimer: deze persoonsgegevens zijn nep):

Persoonsgegevens:

- Voornaam: Wilhelmina
- Achternaam: Kracht
- Burgerservicenummer (BSN): 99473114
- Geslacht: Vrouw

Adresgegevens waarop het bouwplan betrekking heeft:

- Straat: Forum
- Huisnummer: 63
- Postcode: 1315 TG
- Woonplaats: Almere

Figure 7.6: Identity description of Wilhelmina

Om de volgende opdracht uit te voeren, neem je de identiteit aan van iemand die bij de gemeente werkt en aanvragen voor een bouwvergunning verwerkt. Je ontvangt de aanvraag voor een bouwvergunning van Wilhelmina, de aanvraag bevat de volgende informatie: (disclaimer: deze persoonsgegevens zijn nep):

Persoonsgegevens:

- Voornaam: Wilhelmina
- Achternaam: Kracht
- Burgerservicenummer (BSN): 99473114
- Geslacht: Vrouw

Adresgegevens waarop het bouwplan betrekking heeft:

- Straat: Forum
- Huisnummer: 63
- Postcode: 1315 TG
- Woonplaats: Almere

Figure 7.7: Identity description of someone working at the municipality

Next, a task to be executed by the test user is described, each section includes a different task. The tasks are related to the queries in the data story, which in turn correspond to the process model of the use case of a building permit. The specified tasks are:

With the identity of Wilhelmina:

> Task in section 1: Find whether there is a spatial plan tied to the address your building plan relates to. If so, find the spatial plan document.
>
> Task in section 2: Find the spatial area of the spatial plan bound to the address your building plan relates to.

With the identity of the someone working at the municipality:

> Task in section 3: Confirm the personal information of the applicant.
>
> Task in section 4: Find out if the applicant owns buildings, apartments or parcels. If they do, find the address details of these properties.
>
> Task in section 5: Find the surface area of the building and the surface area of the parcel the building stands on that the building plan relates to.
>
> Task in section 6: Find whether there is a spatial plan bound to the address the building plan relates to. If there is, find the spatial plan document.
>
> Task in section 7: Find the spatial area of the spatial plan bound to the address the building plan relates to.
>
> Task in section 8: Find whether there is a public law restriction bound to the address the building plan relates to. If there is, find what kind of restriction this is and from what date this restriction applies.

It is important to note that test users are only asked to perform the task and not to validate the retrieved information. The most important is whether the user is able to find the requested information.

After completing the task, the test user is asked to answer three questions about their experience with the prototype while performing the tasks. The following questions are asked to obtain the opinion of the test user, see Figure 7.8:

- Is it easy to find where the requested information can be retrieved?
- Is the retrieved information clear?
- Is the retrieved information useful?

Wat is uw mening over de volgende vragen gerelateerd aan het uitvoeren van de taak

Is het gemakkelijk te vinden waar de gevraagde informatie opgevraagd kan worden?

Jouw antwoord

Is de opgevraagde informatie duidelijk?

Jouw antwoord

Is de opgevraagde informatie nuttig?

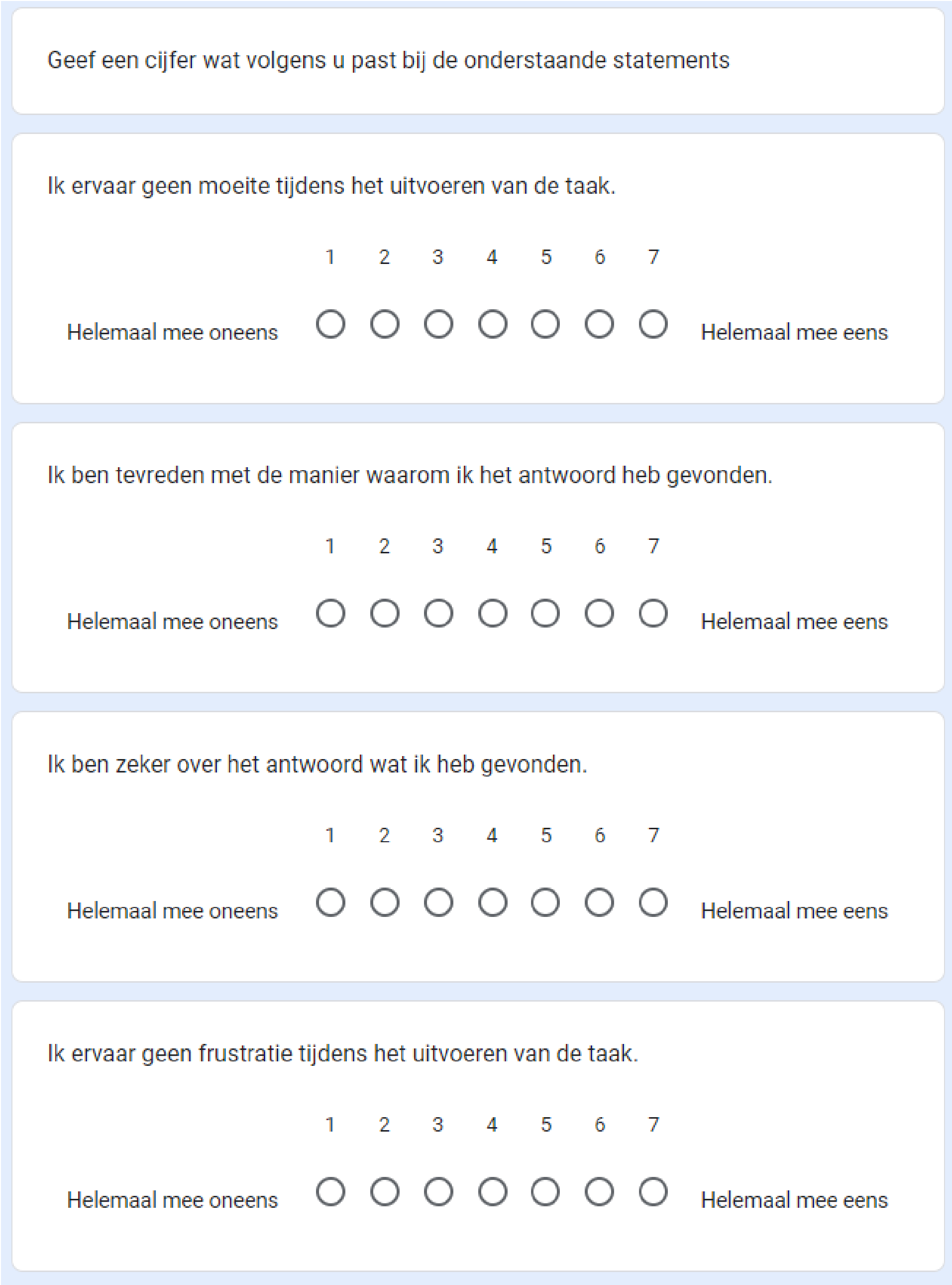
Jouw antwoord

Figure 7.8: Questions about the experience of the execution of the tasks

Next, the user is asked to rate on a scale of 1 to 7 whether the user agrees or disagrees with statements. Where the scores mean the following:
1 = Totally disagree
2 = Disagree
3 = Somewhat disagree
4 = Neutral
5 = Somewhat agree
6 = Agree
7 = Totally agree

The following four statements are asked to rate, see Figure 7.9:

- I do not experience any difficulty while performing the task.
- I am satisfied with the way I found the answer.
- I am confident about the answer I found.
- I do not experience any frustration while performing the task.



Geef een cijfer wat volgens u past bij de onderstaande statements

Ik ervaar geen moeite tijdens het uitvoeren van de taak.

Helemaal mee oneens 1 2 3 4 5 6 7 Helemaal mee eens

Ik ben tevreden met de manier waarom ik het antwoord heb gevonden.

Helemaal mee oneens 1 2 3 4 5 6 7 Helemaal mee eens

Ik ben zeker over het antwoord wat ik heb gevonden.

Helemaal mee oneens 1 2 3 4 5 6 7 Helemaal mee eens

Ik ervaar geen frustratie tijdens het uitvoeren van de taak.

Helemaal mee oneens 1 2 3 4 5 6 7 Helemaal mee eens

Figure 7.9: Statements to rate with a grade

After completing the sections where the user was asked to perform a task, give an opinion and rate statements, a final section asks the user to rate the overall usability on a scale of 1 to 7, see Figure 7.10. Where the scores mean the following:
1 = Very poor ease of use
2 = Poor ease of use
3 = Somewhat poor ease of use
4 = Average ease of use
5 = Somewhat good ease of use
6 = Good ease of use
7 = Very good ease of use

Figure 7.10: Rating of overall usability of the prototype

The final section of the questionnaire concludes with four questions allowing the test user to give general opinion and feedback on the prototype, see Figure 7.11. These four questions aim to gather the user's overall opinion on the prototype's functionalities:

- What do you think is the most useful functionality of the prototype?
- What functionality of the prototype did you enjoy the most?
- What aspect of the prototype limits the usability and usefulness of the prototype most?
- Do you have any other comments/remarks/feedback on the prototype?

Wat is volgens jou de meest nuttige functionaliteit van het prototype?

Jouw antwoord

Welke functionaliteit van het prototype heb je als fijnst ervaren?

Jouw antwoord

Welk aspect van het prototype beperkt de gebruiksvriendelijkheid en bruikbaarheid van het prototype het meest?

Jouw antwoord

Heb je nog overige opmerkingen/aanmerkingen/feedback voor het prototype?

Jouw antwoord

Figure 7.11: General opinion and feedback on the prototype

Usability test results

The next phase of usability testing is to process the results and feedback, draw conclusions and make recommendations for improving the prototype.

A total of 6 test users conducted the usability test. As can be seen in Figure 7.12, the largest group of test users (50%) is represented by students following a study programme without geographical applications, followed by the non-professionals (33,33%), and the professionals (16,7%). The user group of students following a study programme with geographical applications are not represented in this usability test.

Below an overview is given of the tasks in each section, including the main feedback and average scores on the statements about the execution of the tasks. Additionally, the task completion time is shown and discussed.

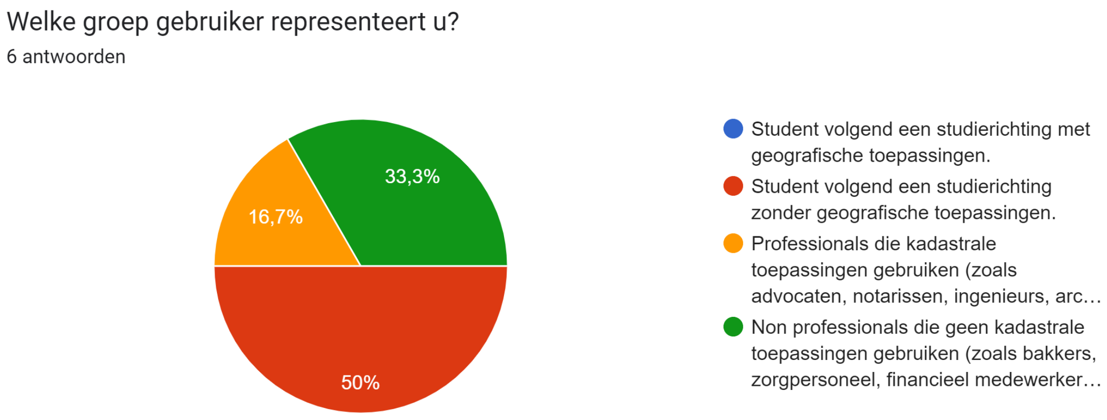


Figure 7.12: Representation of user groups in the usability test

Section 1
Find whether there is a spatial plan tied to the address your building plan relates to. If so, find the spatial plan document.
66,6% of the test users had no specific comments and stated that the information is easy to find, clear and useful. 33,3% stated that the result that appears when there are no spatial plans tied to the address looks like an error, which causes confusion. Also one test user suggested that the query would be easier to find with a clearer heading.
The average score on how easy it is to execute the task: 6.0
The average score on how satisfied the user is about the way they found the answer: 5.3
The average score on the confidence of the retrieved information: 5.0
The average score on the absence of frustration: 5.3

Section 2
Find the spatial area of the spatial plan bound to the address your building plan relates to.
50% of the test users stated that the information was easy to find, the other half of the test users stated that they had to look for it as it was more difficult to find. 83% stated that they had to search and zoom in before being able to find the spatial area. All test users found the information being useful. A general comment was also made by 33,3% of the users about the need for clear headings in order to find the required query.
The average score on how difficult it is to execute the task: 5.5
The average score on how satisfied the user is about the way they found the answer: 4.8
The average score on the confidence of the retrieved information: 5.3
The average score on the absence of frustration: 5.7

Section 3
Confirm the personal information of the applicant.
All test users stated that the information was easy to find and and that the information is clear. 33,3% stated that this is because of the comprehensible language terms being used.
The average score on how difficult it is to execute the task: 6.5
The average score on how satisfied the user is about the way they found the answer: 6.2

The average score on the confidence of the retrieved information: 6.2
The average score on the absence of frustration: 6.3

Section 4
Find out if the applicant owns buildings, apartments or parcels. If they do, find the address details of these properties.
50% of the test users stated that they got confused by the option to enter address information as well as personal information as a variable. Also, confusion was again caused by the result that appears when no information is found, as it looks like an error. All test users did considered the information being useful.
The average score on how difficult it is to execute the task: 5.7
The average score on how satisfied the user is about the way they found the answer: 5.0
The average score on the confidence of the retrieved information: 5.3
The average score on the absence of frustration: 5.7

Section 5
Find the surface area of the property and the surface area of the parcel the building stands on that the building plan relates to.
50% of the test users stated that they missed a legend and therefore did not clearly understand what the areas on the map indicated. Additionally, the area lacks a unit of measurement as stated by 33,3% of the test users.
The average score on how difficult it is to execute the task: 6.0
The average score on how satisfied the user is about the way they found the answer: 5.8
The average score on the confidence of the retrieved information: 6.3
The average score on the absence of frustration: 6.3

Section 6
Find whether there is a spatial plan bound to the address the building plan relates to. If there is, find the spatial plan document.
The previous remarks regarding the need for clear headings, and the result that appears when no spatial plan bound looks like an error also apply to this section. Apart from that, all test users stated that the information is easy to find, clear and useful.
The average score on how difficult it is to execute the task: 5.8
The average score on how satisfied the user is about the way they found the answer: 5.3
The average score on the confidence of the retrieved information: 5.3
The average score on the absence of frustration: 6.0

Section 7
Find the spatial area of the spatial plan bound to the address the building plan relates to.
83,3% of the users expressed that the information is not clear because they have no knowledge of spatial plans. Test users did not understand that a spatial plan can be applied to more than one building, also a legend was suggested to provide more clarity. The one test user who had no comments on the lack of clarity of information was the test user representing the user group of professionals.
The average score on how difficult it is to execute the task: 5.7
The average score on how satisfied the user is about the way they found the answer: 6.0

The average score on the confidence of the retrieved information: 5.5
The average score on the absence of frustration: 6.5

Section 8
Find whether there is a public law restriction bound to the address the building plan relates to. If there is, find what kind of restriction this is and from what date this restriction applies.
50% of the test users stated to find it unclear what the retrieved information means as they are not familiar with public law restrictions.
The average score on how difficult it is to execute the task: 6.3
The average score on how satisfied the user is about the way they found the answer: 5.8
The average score on the confidence of the retrieved information: 5.5
The average score on the absence of frustration: 6.0

Concluding section on general feedback
The average score on the overall usability of the prototype: 5.3

What do you think is the most useful functionality of the prototype?
33,3% of the test users stated to find the multiple search functions (variables) most useful. 66,6% stated to find the most useful functionality being that all information can be retrieved in one web environment.

What functionality of the prototype did you enjoy the most?
33,3% of the users experienced the search function (variables) to be the most enjoyable, 16,7% found the interface in general to be the most enjoyable, and 16,7% experienced the ability to scroll and zoom in/out on a map the most enjoyable. Additionally, 33,3% appreciated the convenience of not having to switch between websites to perform tasks.

What aspect of the prototype limits the usability and usefulness most?
50% of the test users reported that the text was excessive and suggested that clear headings would improve comprehension and facilitate information retrieval. One user experienced the data challenging to read and understand, particularly for those unfamiliar with land administration. Another user reported that having to re-enter data in the search function was perceived as the most limiting.

Do you have any other comments/remarks/feedback for the prototype?
Suggestions for improving the prototype include adding a legend, providing clear headings, providing clearer notifications when no information is found, and displaying pop-ups with information more clearly using, for example, different colours.

Task completion time
The task completion time measures how long it takes users to complete a specific task with a product or service. Figure 7.13 shows the time it took the test users to complete a task in seconds. Each line represents an individual test user. The average time it took the test users to complete a task is shown in Figure 7.14, the figure also shows the trend line indicated by the dotted line. The learning curve theory proposes that a user's efficiency in performing a task improves over time the more the user performs the task [Valamis, 2023]. Figure 7.14 shows

a trend line indicating that task completion time decreases as tasks progress. This implies a learning curve among the test users, which implies that users became more efficient in using the prototype for the execution of different tasks using the prototype.

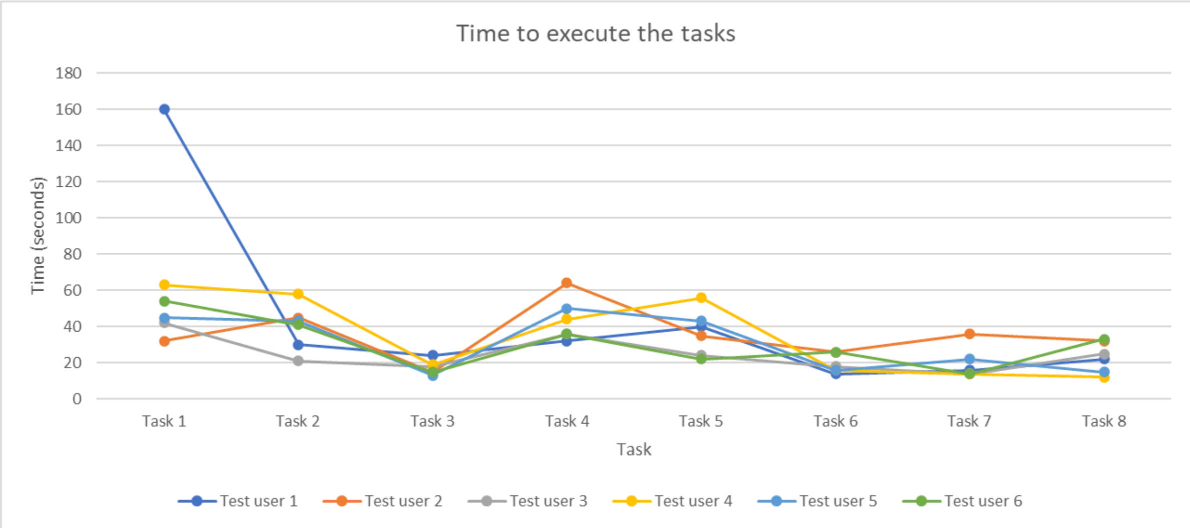


Figure 7.13: Execution time of the tasks by the test users

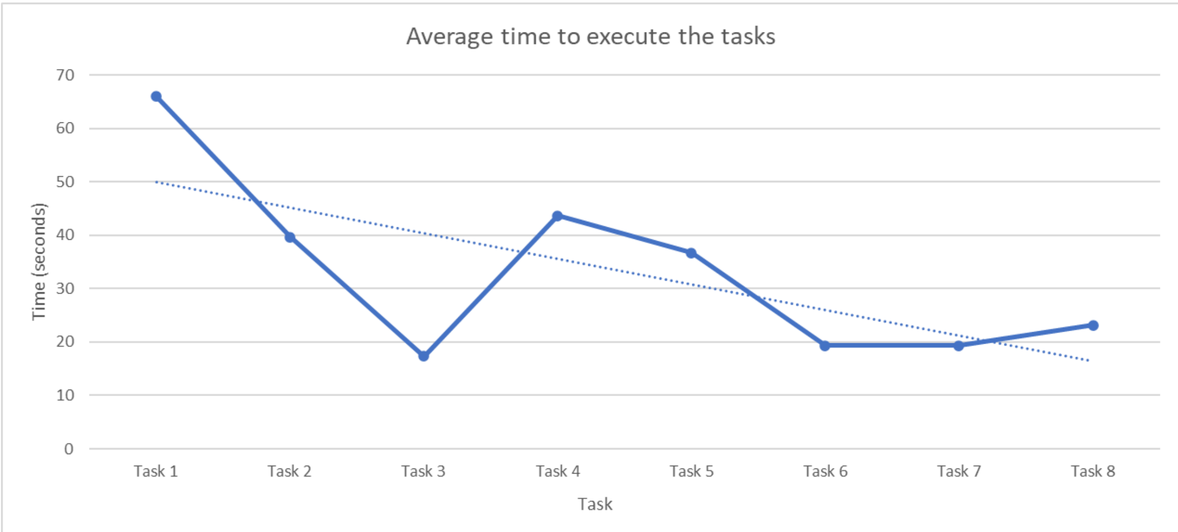


Figure 7.14: Average time it took the test users to execute the tasks

Usability test conclusions

It should be noted that the test imitates a situation and a context, but it is not the real situation itself. This imitation may influence the assessment. In addition, the test users may not fully represent the actual users of the prototype. When applying for a building permit, there are two different types of users: professionals and non-professionals. However, in the test, both perspectives are assessed by the same test user.

The objective of the usability test was to assess the usability of the prototype. The findings indicate that users are able to complete the tasks and retrieve the required information for the use case of a building permit, and that users appreciate not having to switch between different web environments to retrieve the information. However, the information retrieval in the prototype was found to be dependent on clear headings. Queries with relevant terms in the headings are recognized. Test users representing the non-professionals and students following a programme without geographical applications understood the retrieved information better when standard language was used. The task completion time indicated that users become more proficient in using the prototype as they carry out more tasks.

Recommendations for improving the prototype include using clear headings for queries, using standard Dutch language, and including explanations for land administration domain-specific terms. Additionally, a legend and pop-ups are recommended to be added when information is displayed on a map. Further research should test these additions through a new usability test. Further research should also include the assessment by test users more applicable to the context, such as professionals working for the municipality.

The assessment and evaluation of the data stories have shown that the implementation of LADM with linked data for data dissemination in the Netherlands has several benefits regarding time efficiency, resource efficiency and usability. However there is a preference for the current state of the use cases when considering the completeness, reusability and data accuracy of the data. The next chapter will discuss the findings of this study and will elaborate on limitations.

8. Discussion and limitations

This chapter presents and discusses the findings of this study in Section 8.1, including shortcomings, improvements and challenges encountered. Additionally, limitations of this study are discussed in Section 8.2.

8.1. Discussion

8.1.1. Problem statement

At the beginning of this study a problem statement was defined, stating that registers and geoportals in the Netherlands use different approaches to information delivery, processing and retrieval, which may lead to interoperability problems between them. While one source supports this statement about interoperability [Çağdaş and Stubkjær, 2014], no comprehensive study can be found about the consequences of these differences between registers and geoportals in the Netherlands and what problems they cause. Therefore, the question may arise: is there a problem worth solving?

The Kadaster has developed the Kadaster Knowledge Graph to link different registers. The resulting Loki chatbot has proven to be effective. So why should there be a different kind of approach, and therefore a different ontology, to link registers in the Netherlands? The KKG is already more or less doing the same as LADM by providing semantics for different datasets in an integrated model. Extending the existing KKG ontology to evaluate the inclusion of other registers such as the WOZ dataset would have been a more efficient approach. Perhaps a study on interoperability problems between countries would have been more valuable. In such a study there would be compelling argument for using LADM, as it is a conceptual model and an international standard.

8.1.2. Use cases

Given the limited time frame, it was decided at the beginning of this study to examine two use cases in order to assess and evaluate the implementation of LADM. These use cases were selected based on their common occurrence in the Netherlands. However, it is important to note that the selected use cases may not provide the best evaluation of the implementation of LADM for data dissemination in the Netherlands. For example, not all phases of the use cases require consultation of multiple registers, which is necessary to demonstrate the full application of LADM. Furthermore, it was not possible to access all the registers that needed to be consulted during the use cases using LADM, as the Kadaster did not have administrative access to all of them. It could be argued that it would have been better to select use cases where multiple registers were consulted in each phase and where each consulted register could be accessed, in order to provide a comprehensive overview of the LADM implementation.

In addition, the prototype is currently limited to a number of queries for querying the data, as only two use cases have been taken into account. It is debatable how representative this limited prototype is of the entire LADM application, and therefore the evaluation is based solely on the current state of the prototype. The assessment of the metric 'usability' may differ when multiple use cases are included, as it becomes more challenging to retrieve information. The same applies to the 'scalability' metric, which has not yet been tested to determine how scalable the prototype is. The assessment is based on own experience, assumptions, expert opinions, and previous research on the Loki chatbot. Only practice will reveal whether scaling up is possible or involves unforeseen difficulties. The same applies to the assessment of 'time efficiency' and 'reusability'.

8.1.3. Country profile

In the development of the country profile it was decided to use previous research as a starting point. This relates to core LADM and Part 4 - Valuation information [ISO, 2012] [Kara et al., 2019]. However, it is important to note that relying on previous research may have resulted in a biased view of the land administration systems in the Netherlands and how they affect the country profile. Perhaps the country profile would have been adjusted differently if it had been approached from a more objective point of view. For instance, merging the classes of BAUnit and spatial unit. Initially, it was assumed that BAUnit should be included as a stand-alone class in the Netherlands based on previous research from 2012 and 2019 [ISO, 2012] [Kara et al., 2019]. However, this assumption may not have been properly scrutinised, and it is possible that other similar decisions have been overlooked due to a lack of critical review.

8.1.4. Initial ontology testing

After developing the country profiles, which represent the ontology, no initial testing was conducted. The purpose of initial testing of an ontology is to validate its basic functionality and correctness. This testing lays the foundation for further development and refinement of the ontology, where any errors and shortcomings can be identified and corrected before wider implementation [Blomqvist et al., 2012]. Ontology testing would be valuable for the country profile of spatial plan information. This is because a country profile of the Netherlands for spatial plan information has not been developed before. Nevertheless, no initial testing was performed in this study that could have exposed possible inaccuracies in the ontology. Therefore, it is debatable whether there are inaccuracies in the ontology that have not yet surfaced during implementation.

8.1.5. UML relationships and cardinality in Protégé

The country profiles are modelled in UML using various relationships, such as association, inheritance, aggregation or realization, each indicating a different function. These models were then transformed into an OWL model using Protégé. However, it was not possible to indicate these functions on relationships between classes in Protégé.

A relationship in the UML model may indicate that it is a required relationship indicated by a closed diamond, meaning that the child class cannot exist independent of the parent class. However, this relationship cannot be indicated in the OWL model, resulting in the child class being able to exist without the parent class being present, which should not be possible in the LADM world. Since the ontology makes no mention of this, it is impossible to know whether such situations occurred during the implementation of the ontology, except if every relationship is checked. One could load incorrect data without knowing.

The same applies to the cardinality attached to relationships between classes. In the country profile of valuation information, a cardinality of 0,2..* is used, which means that a class can contain 0 or 2 or more (*) of the other class. However, in Protégé it is only possible to specify one minimum value, not two. Therefore, it was decided to define the cardinality as MIN 0, which implies 0..*. Thus, in this case the cardinality is not defined in accordance with the country profile, which may lead to an inaccurate set of values when retrieving data.

Finally, it should be noted that Protégé does not have the ability to set cardinality on data properties, unlike the cardinality on attributes defined by LADM. It is likely that Protégé automatically assigns a cardinality of 1 to data properties, indicating that only one value is expected per attribute. If an attribute has no known data value in the implementation, it may appear as an error. However, this is not always the case when considering the cardinality of the attributes defined by LADM. Alternatively, it could mean that only 1 value is displayed when data is requested, whereas multiple values can be assigned, according to the cardinality of the attributes defined by LADM.

Because of the shortcomings of the ontology software mentioned above, it is questionable whether the ontology is represented accurately enough for implementation, as it does not conform completely to the UML country profiles.

8.1.6. WOZ dataset

The Kadaster does not manage the WOZ data, therefore fake data was used which was created specifically for this study. However, the NL_WOZ-Value dataset was not created in accordance with the WOZ dataset managed by the Council for Real Estate Assessment. The WOZ dataset for the ontology implementation was created based on the minimum data attributes required to retrieve the requested information for the use cases. It could be that data from the official WOZ dataset cannot be retrieved once it is included in the ontology, depending on how the dataset is structured. Therefore, it is debatable whether the current linking of WOZ data is accurately represented in the ontology.

8.1.7. Datasets in the ontology

This study included only the datasets and data attributes in the ontology that were necessary to query the use cases in the data story. Other datasets are not explicitly created and loaded because they are not needed and used in the use cases. This study revealed that possible inaccuracies in the ontology become apparent during the implementation of the datasets, in this case a missing relationship between SP_PlanUnit and LA_SpatialUnit. It is thus debatable whether the feasibility of LADM in the Netherlands can be determined on the basis of this study. Because inaccuracies in the ontology arise while querying the data for these use cases, and are identified when all classes of the ontology are populated with data, which is not the case in this study.

8.1.8. Assessment method

There is no single appropriate method of assessment presented in the literature for a data story resulting from an ontology filled with data. Therefore, the assessment method used is self-selected and not foolproof. It is possible that other methods may offer more accurate evaluation.

8.1.9. Subjectivity in assessment and evaluation

There is subjectivity in the selection of the criteria for assessment. The criteria can be seen as the desired things for evaluation. As indicated earlier in this thesis: 'The first level of difficulty is to decide on the relevant assessment criteria', as it has been the sole responsibility of the evaluator to determine the elements to evaluate. This brings about the issue of subjectivity in deciding which criteria makes the desiderata. This has largely been the issue with most of the approaches in assessment since there has to be a criterion that decides the overall quality or correctness of the ontology. After establishing the criteria, it is important to acknowledge that subjectivity also exist during the assessment of metrics. This subjectivity is specifically present in non-measurable metrics, such as usability, and less so in measurable metrics, such as time efficiency.

8.2. Limitations

Time This study was conducted within a limited time span. Because of this limited time decisions had to be made regarding the use cases, datasets and geoportals. These choices were based on being able to develop a generalized evaluation and conclusion on the linked data portal with LADM implementation in the Netherlands. The result is that not all elements present in the land administration systems of the Netherlands are included, for example the underground infrastructure and water boards. Furthermore, because of the limited time span, an overview was developed regarding which datasets needed to be created and included in the ontology to provide for the use cases. Because of the choices in use cases, datasets, geoportals and datasets in the ontology, it was not possible to conduct a complete evaluation of LADM implementation in the Netherlands.

Developments in the Land Administration Domain Model LADM consists of 5 parts of which only one part has been officially accepted. Because 4 parts, of which 3 included in this study, are still in development and are undergoing changes, it can be that this study is less applicable in the future because of changes in the LADM parts. This study can serve as an example of how these parts could be applied and implemented in the Netherlands. Nevertheless, this study cannot be simply copied, and attention should be paid to developments in LADM, and whether these changes influence the implementation of LADM in the Netherlands.

Data sources Kadaster maintains several important registers in the Netherlands, but it does not manage all datasets from which information is requested in the use case processes. As a consequence, the registers they do not manage were not able to be included in the ontology and prototype data story. LADM can only be applied to the range of datasets there is access to. The WOZ data, guardianship and administration register, bankruptcy register, VIS, and HR are dataset Kadaster currently has no access to. Cooperation between register administrators in the Netherlands could enhance the value of the implementation of LADM by enabling the inclusion of more registers in the ontology.

Fake BRP data The base register of persons (BRP) contains personal data that is not publicly available due to privacy laws. The Kadaster is not permitted to release this data for research purposes, so fake data was used in this study. The fake data has the same structure as the real BRP data, but this remains a limitation within this study as it was not possible to test the actual content and quantity of data.

Fake WOZ data In the use case of real estate transaction, data from the WOZ is accessed in combination with data from the BAG, BRK, and BRK-PB. It is important to note that the WOZ data used in this study is fictitious, as actual WOZ data is managed by the Council for Real Estate Assessment and is not accessible by the Kadaster. The fake WOZ data used in this study may not be conform the official WOZ data registration as only attributes are included necessary for the use cases.

Spatial plan data During implementation only data that is available as linked data could be included in the ontology, as the data needs to be available as triples to be able to be linked to each other. For spatial plan data, this was only available for the municipality of 'Zeewolde'. The data querying was limited to this city as a consequence. The limited scope of the data means that interesting cases, such as usufruct, could be absent or less prevalent.

This chapter discussed the findings of the study and outlined its limitations. The following chapter will answer the sub-research questions and the main research question, and provide recommendations for future research.

9. Conclusion and future research

This study ends with an assessment of the research questions in Section 9.1. First the sub-research questions are addressed, providing answers to both the literature review and the implementation phase of this study. These questions will be answered in a logical order, and on the basis of these sub-questions the main research question is addressed. Additionally, recommendations for future research are provided in Section 9.2.

9.1. Conclusions

What are relevant use cases to demonstrate the potential added value of applying the LADM Edition II within the context of the Netherlands?

Use cases that require consulting multiple geoportals can demonstrate the potential of LADM implementation. These use cases include buying and selling real estate and applying for a building permit. When buying or selling real estate, it is necessary to consult various registers such as the base register of addresses and buildings (BAG), the bankruptcy register, the guardianship and administration register, the identity verification register (VIS), the base register of persons (BRP), the commercial register (HR), the public register (BRK), the public law restrictions (BRK-PB) and the Wozwaardeloket geoportal. When applying for a building permit, spatial plans are consulted via Omgevingsloket geoportal, together with information from the base register of persons (BRP) or the commercial register (HR) and public law restrictions (BRK-PB). It is important to note that the new Environment Act, which came into effect on 1 January 2024, requires spatial plans to be accessed from the Omgevingsloket website instead of Ruimtelijkeplannen. These two use cases can demonstrate and evaluate the implementation of the LADM for data dissemination in the Netherlands. The process of these generic cases, which occur regularly in the Netherlands, were visualized as process models.

What is the state of the art on the LADM Edition II?

The Land Administration Domain Model's revised version comprises five parts. The first part presents the generic conceptual model of LADM, which includes the party package, the administrative package, the spatial unit package, and the generic conceptual model package. This part has already been accepted as an ISO standard. The second part of the model provides a more detailed description of the classes introduced in the first part. Also, the second part introduces the survey and representation package which, along with Part 1, forms the core of LADM. Part 2 is in the DIS stage and has not yet been officially accepted and adopted as a standard. Similarly, parts 4 and 5 are also in the DIS stage and are also not yet officially accepted. Part 4 describes valuation information in land administration and builds upon the core of LADM. The final part of the model includes the registration of spatial plan information and is also based upon core LADM. All parts are visualized in UML, displaying the relationships between classes. Part 5, which provides information on spatial plans, is particularly interesting as it is a newly developed part, with the fewest developed country profiles.

How can the country profile of the Netherlands be conceptually modelled as it pertains to parts 1, 2, 4 and 5 of the LADM Edition II, and what are the intended and unintended consequences in this modelling?

During the development of the country profile for core LADM a required relationship was added to the class LA_RRR as a result of developments from the first version of LADM. Additionally, a modification was made to the class LA_BAUnit. It has been concluded that, currently in the Netherlands, there is no distinction between a basic administrative unit and spatial unit. Therefore, the class LA_BAUnit has been merged with the class LA_SpatialUnit. It also has been decided to model the class LA_Mortgage as a subclass of LA_RRR, as the Kadaster Act does not make a distinction between a right and restriction. An external class has been added, namely NL_Address to cover country-specific information related to spatial units and addresses. Furthermore, to indicate that public law restrictions are included within expected land use, a new class NL_PublicLawRestriction has been added. Subsequently, NL_PublicLawRestriction is defined as a subclass of LA_RRR as it is a type of restriction. NL_PublicLawRestriction results in the addition of a new class NL_SpatialUnitRestriction which has a relationship with LA_SpatialUnit. This relationship indicates a restriction imposed on a spatial unit resulting from a public law restriction. Finally, the class NL_RegulatoryArea has been added, which indicates the area of application of the public law restriction.

For the valuation information part of the country profile, the country profile developed in previous research was used as a basis incorporating multiple country-specific classes, including NL_WOZ-value, NL_WOZ-object, NL_WOZ-subobject, and other WOZ-interest classes, as NL_Transaction and NL_MarketAnalysis, which are the result from the WOZ database [Kara et al., 2019]. These classes are related to classes in other registers, such as buildings, transaction prices, and parties. Additionally, the NL_WOZ_Building, NL_WOZ_OccupancyUnit, NL_WOZ_Parcel, NL_WOZ_Subject and NL_ValuationUnitGroup classes have been added to represent additional object characteristics used in property valuation in the Netherlands. Changes have also been made by the addition or removal of relationships on or between classes in the country profile due to developments in Part 4 - Valuation information.

In the development of the country profile for spatial plan information, to indicate that public law restrictions are a part of land use planning, a relationship has been established between the country specific class NL_PublicLawRestriction and the class SP_PlanBlock which includes recommendations or expected land uses.

The development of the country profile for the Netherlands has led to a simplification of the model, by removing unneeded classes, and to a better adaptation to the country-specific needs of the Netherlands.

How can linked data be employed to implement the conceptual model of the country profile of the Netherlands based on LADM Edition II, and what are the intended and unintended consequences in this implementation?

For each UML country profile, an OWL ontology model was created in Protégé to define the model system's structure. These ontologies consist of classes, relationships with cardinalities, object properties, and data properties with their respective data types. The three individual ontologies were merged as they contained the same core classes. After creating one resulting ontology, the next step was to create datasets based on the classes and attributes in the ontology using SPARQL construct queries. If a class in the ontology did not correspond one-to-one with a class from a Dutch register, a new dataset had to be created. Therefore, a comprehensive understanding of the Dutch registers was essential to identify where specific data is registered. It became apparent that not all attributes defined in LADM are registered in the Dutch registers. In contrast, the Dutch registers contain more attributes than those defined by LADM. It was therefore necessary to iterate the list of attributes.

During the implementation with linked data the ontology was evaluated. During the implementation process it was discovered that a direct relationship was missing between the class SP_PlanUnit and the class LA_SpatialUnit, which was subsequently added. The implementation also demonstrated the possibility of linking data from different registers based on the ontology. When implementing LADM with linked data it is important to check not only the relationships between the classes but also the attributes of the classes.

Finally, the question remains as to whether significant changes to class attributes will affect cross-border interoperability. The more the attributes of classes differ from the standardized LADM model, the less likely interoperability is with other countries using the model due to the greater differences. Interoperability remains between classes, but not on the attributes of the classes.

What are the intended and unintended consequences following the LADM-based approach in the use cases as demonstrated through the developed prototype?

Data storytelling simplifies complex information to enhance audience engagement with retrieved data. For the evaluation of LADM implementation, a prototype in the form of a data story was created to query and assess the selected use cases based on various metrics, including time efficiency, resource efficiency, data accuracy, completeness, usability, accessibility, resource optimization, scalability, and reusability. A comparison was made between the current state of the use cases as indicated in process models and the LADM-based approach. Also, a usability test was conducted to evaluate the usability of the prototype in more detail.

The assessment finds that the LADM-based approach offers significant efficiency gains in terms of time and resources. This is due to the ability to retrieve specific information without the need to search and switch between multiple registers or geoportals. All necessary information can be found on a single web page, the data story prototype. The assessment also finds that usability and accessibility is improved with the LADM-based approach. For scalability and resource efficiency, the LADM-based approach is preferred, although to a lesser extent than the other metrics. This is because the value of these metrics cannot be fully assessed due to the limited scope of this study. Based on the metrics of completeness, reusability, and data accuracy, the current state of the use cases is preferred. Although, it should be noted that the completeness has not yet been fully proven in the LADM implementation. This is due to the limitations of this study, which only validated LADM for the use cases and a limited scope. The data is limited to selected registers, the municipality of 'Zeewolde', and a limited number of queries for retrieving the data. This has led to limited reusability of the retrieved data, as the specific data may not be applicable in many other contexts. The accuracy of the data depends on how frequently the datasets in the triple store are updated, making it highly variable.

As desired, the evaluation of use cases has demonstrated the current capabilities of implementing LADM within the limited time frame of this study. However, the limited scope of this study makes it difficult to draw a convincing conclusion on the wider implementation of LADM based solely on the questioning of the use cases.

Based on the answers to the sub-research questions, the main research question can be answered.

What are the benefits and drawbacks of a linked data portal based on the Land Administration Domain Model (LADM) Edition II concepts?

The objective of this study was to identify the benefits and drawbacks of the implementation of LADM Edition II for data dissemination in the Netherlands with a linked data portal. The study demonstrates that to evaluate the implementation of LADM, it is necessary to determine and model use cases. The current state of LADM Edition II needs to be evaluated, and in order to adapt LADM to the country-specific needs of the Netherlands, a comprehensive review of the Dutch land administration systems should be carried out, whereupon UML country profiles can be developed. These country profiles should then be converted into an OWL ontology model to enable the implementation with linked data. Next, datasets based on the Dutch registers are to be created with SPARQL construct queries, in accordance with the ontology. Finally, to assess and evaluate the use cases with a data story, it is necessary to develop SPARQL queries for querying the data. The benefits and drawbacks of the implementation of LADM Edition II in the Netherlands are stated in Table 9.1 and discussed in more detail below.

<table>
<tr><td>Benefits</td><td>Drawbacks</td></tr>
<tr><td>Time efficiency.</td><td>Validation of the country profile.</td></tr>
<tr><td>Resource efficiency.</td><td>Creation of datasets conform the ontology.</td></tr>
<tr><td>Usability.</td><td>Verification of the attribute lists.</td></tr>
<tr><td>Enables Kadaster to develop, implement and maintain land administration systems more efficiently.</td><td>Data must be in linked data format.</td></tr>
<tr><td rowspan="2">Enables users to access information in a way that is clear and understandable to locals, foreigners and machines.</td><td>Only data that is accessible and publicly available can be included.</td></tr>
<tr><td>Writing of SPARQL queries for querying of the data.</td></tr>
</table>

Table 9.1: Benefits and drawbacks of a linked data portal based on the Land Administration Domain Model (LADM) Edition II concepts

The implementation of LADM in the Netherlands has the potential to offers several benefits, including time efficiency, resource efficiency, and usability. By linking multiple registers from different land administration domains, the LADM-based approach enables the consultation of only one geoportal, as demonstrated by the data story. This is particularly beneficial in situations where consultation of multiple registers and/or geoportals would normally be required.

This feature enhances user experience by providing easy access to all necessary information in one place, and reducing the time and effort required to retrieve data. Looking at the broader characteristics of LADM, there are more benefits to be highlighted. LADM as a spatial domain standard enhances domain-specific standardisation and captures semantics of the land administration domain on top of basic standards for geometry, observations and measurements from the field. LADM enables land registry and cadastral organisations, such as Kadaster, to develop, implement and maintain land administration systems more efficiently. Formalized semantics used in LADM allows users to access information in an unambiguous and understandable way. As a result, foreigners can understand and trust the content of a LAS as well as locals, because the meaning is unambiguous and clear to outsiders, such as foreigners, but also to machines [Van Oosterom and Lemmen, 2015]. Furthermore, the data model for INSPIRE cadastral parcels has been prepared in a way that supports compatibility with LADM. INSPIRE cadastral data is based on LADM and it is therefore likely that the industry will also develop products that are compatible with LADM, such as ESRI or Trimble [European Union, 2020].

To implement the LADM-based approach, a significant investment will be required. The country profile must be validated, and datasets must be created in accordance with the ontology using SPARQL construct queries to fill the classes of the ontology with data. This process involves verifying whether the attributes defined in LADM match the attributes registered in the Dutch registers. To fill a class of the ontology, the correct attributes must be included in the correct dataset. This requires a comprehensive understanding of the Dutch land administration systems to determine the source of the data attribute and the relationships attached. This process must be repeated for each additional register that is to be included in the ontology. Attention must be to the fact that these new datasets must contain data in the linked data form. Therefore, it is not possible to directly include raw data in a new dataset. Also, registers can only be included if there is access to the datasets, and the dataset can be made publicly available. Following, data retrieval requires writing SPARQL queries. Each new query necessitates writing a new query, and requires a good understanding of the ontology to identify the necessary relationships between classes. The validation of all possible queries can be a time consuming process. It remains to be seen whether the potential benefits of implementing LADM for data dissemination in the context of the Netherlands are worth the investment required for implementation.

9.2. Future research

Limitations and potential areas for improvement were identified during this study, leading to potential valuable future research. This section provides recommendations for future work.

Use cases At the beginning of this study, two use cases were identified to evaluate the application and implementation of LADM in the Netherlands. The decision to select only two use cases was made because of the limited time span of this study and to keep the complexity within limits. In order to evaluate more data and other domains of data, e.g. waterboards and underground networks, future research should identify more use cases and more complex situations in order to better evaluate the implementation of LADM in the Netherlands. Defining other use cases not only results in the inclusion of more datasets and different types of datasets, it can also provide better evaluation on the application of LADM in the Netherlands.

Part 3 - Marine space georegulation The scope of this study is limited to above-ground land elements only, thus excluding underground networks and water boards. This means that during the development of the country profile, Part 3 was excluded and also not taken into account during the development of the ontology and implementation. Further research should determine what the country profile of the Netherlands will look like with regard to Part 3 – Marine space georegulation. This addition will subsequently mean that datasets related to water authorities, such as water regulations, can also be included during the implementation.

Base registers and geoportals During this study, the selection of base registers and geoportals considered was aligned with the scope of this study and use cases. The six registers and geoportals included were BAG, BRK, BRK-PB, WOZ, spatial plans, and Wozwaardeloket. The Netherlands has a system of 10 base registers and several more valuable geoportals, such as PDOK and Kaartenvannederland, which are relevant at the national level. Future research should examine the complete set of base registers and geoportals in the Netherlands and adapt the country profile accordingly. This could benefit for example industry support and aligning of portals with easier interpretation, as it is based on an international standard. Their inclusion could be evaluated during implementation using appropriate use cases.

Utility networks To maintain simplicity, this study excludes underground networks from its scope. However, including underground networks is essential for land administration in the Netherlands. Pipelines and cable lines run underground through multiple parcels of land, each with different rights attached. As a result, legal complexities can arise around these pipelines. Future studies should investigate the proper inclusion of underground legal spaces in LADM within the Netherlands. Implementation with LADM will need to evaluate its ability to accurately register these legal matters.

Other registers As previously mentioned, the ontology does not include data of the guardianship and administration register, bankruptcy register, VIS, and commercial register (HR) as the Kadaster does not manage these datasets. Since LADM provides a comprehensive model including different domains of land administration these would be possible to include. Cooperation between administrators of registers could enhance the value of LADM in the Netherlands. This would allow for the inclusion of registers in the ontology that are not managed by Kadaster. Future research should determine the feasibility and impact of such cooperation and dataset inclusion.

Authorization This study evaluated use cases that query the base register of persons (BRP), which is a register that is not publicly available. The inclusion of the base register of persons in the ontology is demonstrated using fake data. However, if LADM were to be implemented in the Netherlands, such protected registers could not be included in the model as they cannot be made public. Future studies should investigate the possibility of partially shielding these protected registers and making them accessible only to authorized individuals. The Kadaster is currently undertaking a project named 'Locked Unlocked' to investigate and test these possibilities. It is necessary for future research to determine whether this is also possible for the implementation of LADM.

Attribute list During implementation, it became apparent that the attributes defined in LADM do not match the properties registered in the Dutch registers. Any attributes defined by LADM that are not registered in the Dutch registers should be removed from the attribute list. To conform the ontology to the Dutch registers, it is necessary to review each class and its attributes defined in LADM, and determine if it is registered in the Netherlands. There may be additional attributes registered in the Netherlands that are not yet included in attribute lists defined by LADM, as was the case for 'houseletter' in the class 'NL_Address' for example. In such cases, these attributes must be added to the appropriate class. Further research is required to determine the country-specific attribute lists in accordance with Dutch registers to update the country profile. The purpose of this research is to identify the attributes that need to be extracted from the Dutch registers to create new datasets conform the ontology. This will save time during LADM implementation at the data level.

Datasets in the ontology This study only included datasets for the classes necessary to query and evaluate the use cases. However, to fully evaluate the ontology, all classes should be filled with datasets. Further research is required to determine whether the use cases return the same data when all classes in the ontology are populated with data. Unexpected limitations may arise, which may require adjustments to the ontology. Furthermore, the query time may significantly increase due to the large number of datasets, which could have a negative impact on usability. It is recommended that further research is conducted to evaluate use cases when all classes are filled with data.

Assesement of the prototype In this study, assessment of the data story was based on literature, expert consultation, a usability test and personal experiences. To improve the objectivity and quality of the assessment, it is recommended to involve multiple assessors from diverse fields of expertise and backgrounds.

Time assessment In this study an assessment was made based on a time metric, this time assessment is based on own experience and literature. However, this assessment has a large variability due to simple and complex cases, and the assessor has a certain bias. To obtain a more accurate assessment of the time required to perform certain tasks, further research should be conducted with multiple participants from different domains, ages, and backgrounds. A more objective assessment would provide greater insight into the time required for tasks when LADM is implemented, compared to the current situation. This time assessment can also be used in a cost analysis, which will be discussed in the next paragraph.

Cost analysis During the evaluation of the prototype, it was decided not to carry out a cost analysis due to insufficient knowledge about the economic aspects of the use cases at short notice. A separate study will be necessary to calculate the costs of performing certain tasks for the use cases, taking into account the time and resources required. By conducting this assessment, a more accurate evaluation can be done on the economic aspect, potentially leading to a new perspective on the implementation of LADM.

Part 6 - Implementation A new OGC Standards Working Group (SWG) LADM, this will be Part 6 of LADM, is being formed and will be voted on March 28, 2024, addressing LADM implementation. This thesis study serves as an first example of how LADM can be implemented using linked data. Further research should test and evaluate different methods for implementing LADM, providing a wide range of implementation options and their respective advantages and drawbacks.

Cross-border interoperability As stated in Section 1.2, 'Considering the broader international context, the implementation of an international standard at the national level would represent a significant advance towards achieving interoperability between countries.' This study only examined the implementation of LADM within the borders of the Netherlands. Further research should investigate the feasibility of achieving interoperability at border areas, such as those with Belgium, Germany, and Luxembourg, through the implementation of LADM. To do so, a country profile of the neighbouring country must first be created and implemented. The degree of interoperability can then be tested by querying data at these border areas. Demonstrating the consequences of implementing LADM in an international context could motivate other countries to adopt LADM within their own borders.

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A. LADM implementation with linked data

Çağdaş and Stubkjær (2014) conducted a research that contributed to the linked data approach, by developing a conceptual model and RDF schema that can be used for presenting land administration data as linked data, as an extension of Government Core Vocabularies [European Commission, 2015] which provides a generic approach for a data model based on core vocabularies. This extension enables the representation of the datasets kept in the registers.

In a later study, Çağdaş and Stubkjær (2015) developed a KOS in the form of a thesaurus for the domain of cadastre and land administration to further contribute to linked data administration. The thesaurus is mainly derived from the terms of the Land Administration Domain Model, and should provide a basis for further ontology development initiatives. The interrelated core domain terms of the developed thesaurus are supposed to improve finding and retrieval of information, thereby organizing domain knowledge. The development of the Cadastre and Land Administration Thesaurus (CaLaThe) was accomplished using the 2005 Guidelines for the Construction, Format, and Management of Monolingual Controlled Vocabularies, following the steps: term SELECTion, identification of semantic relationships, and specification of these relationships. The resulting CaLaThe is based on Simple Knowledge Organization System (SKOS), structured in RDF format and available online at the website Cadastre and Land Administration Thesaurus - CaLAThe (cadastralvocabulary.org) as an enriched and terminologically specified version of the LADM ISO standard that presents and relates core terms of the cadastral domain in SKOS format (Semantic Web) [Stubkjaer and Cagdas, nd].

B. Classes in the ontology

The classes in the OWL ontology model with associated attributes and relationships are visualized below.

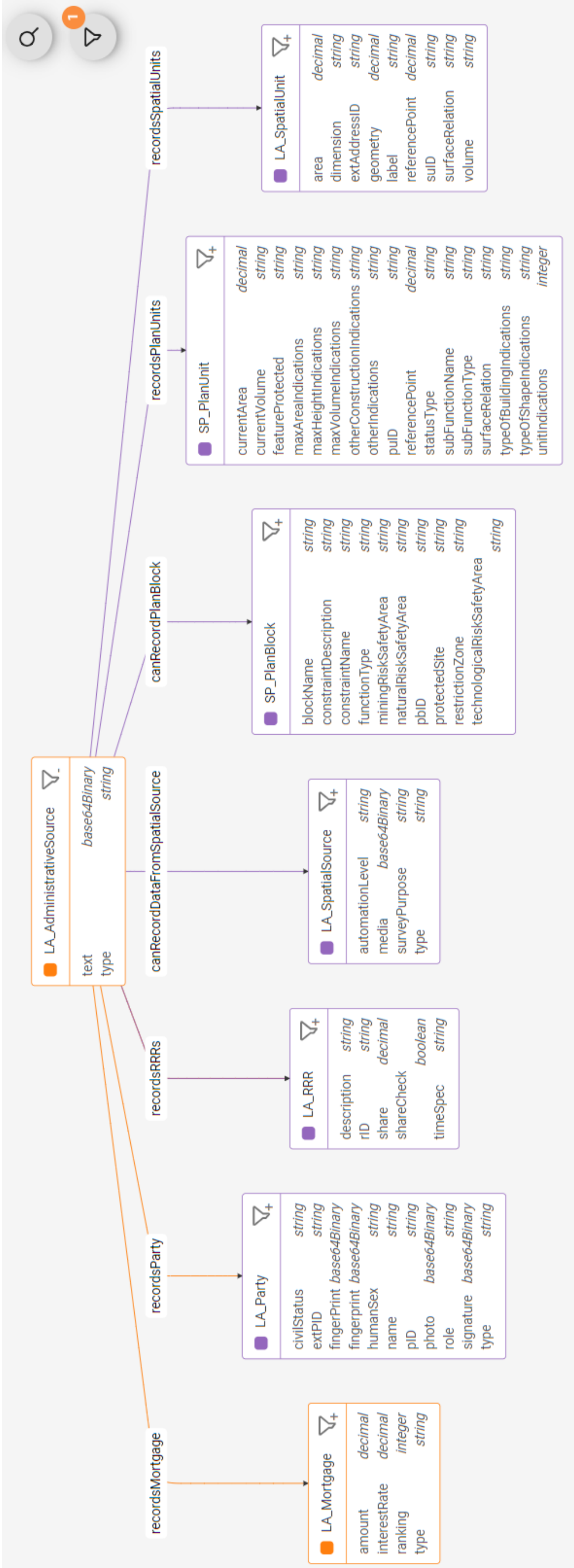

Figure B.1: Class LA_AdministrativeSource

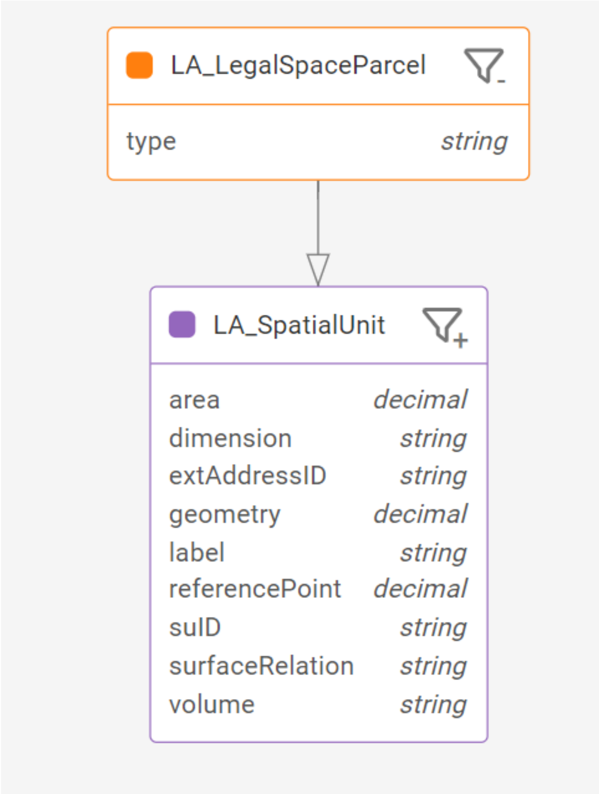

Figure B.2: Class LA_LegalSpaceParcel

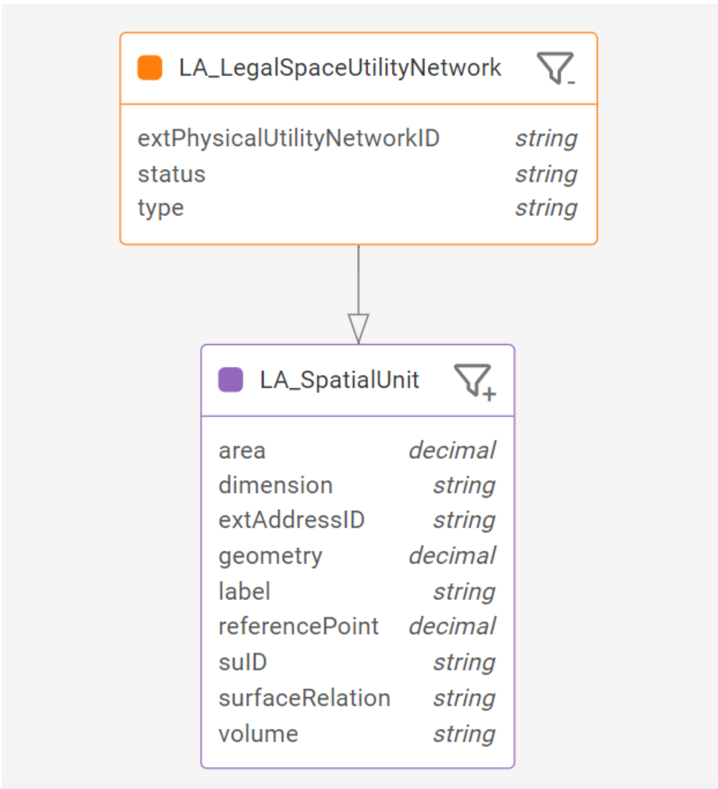

Figure B.3: Class LA_LegalSpaceUtilityNetwork

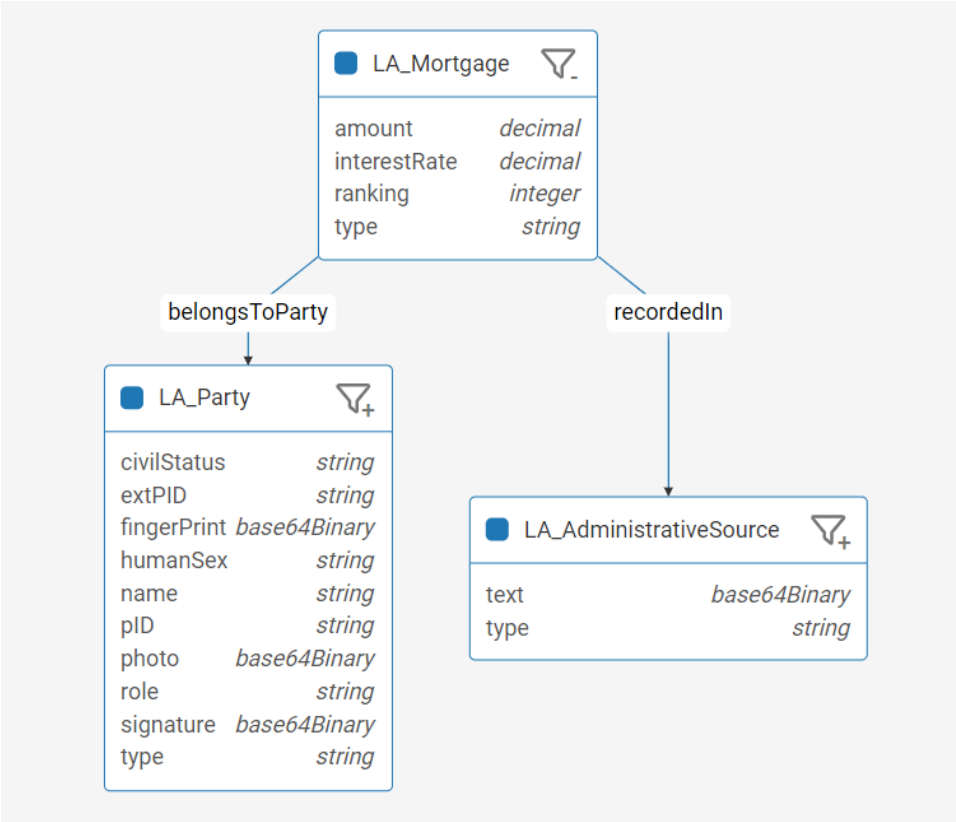

Figure B.4: Class LA_Mortgage

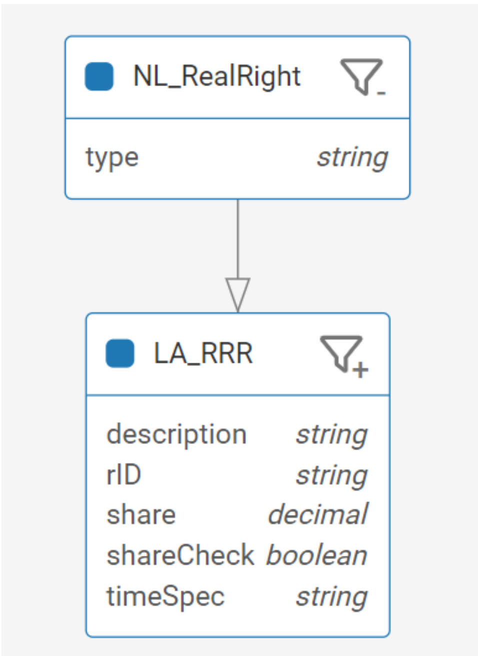

Figure B.5: Class LA_RealRight

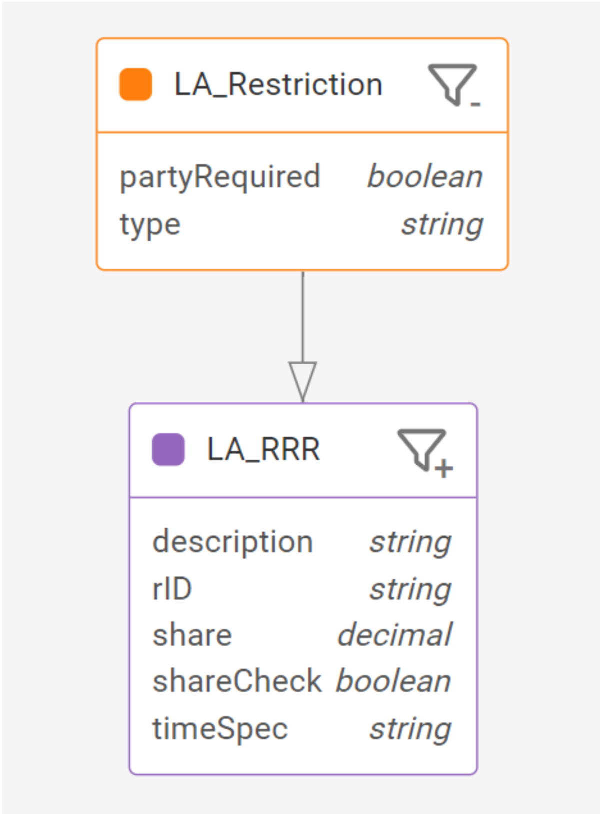

Figure B.6: Class LA_Restriction

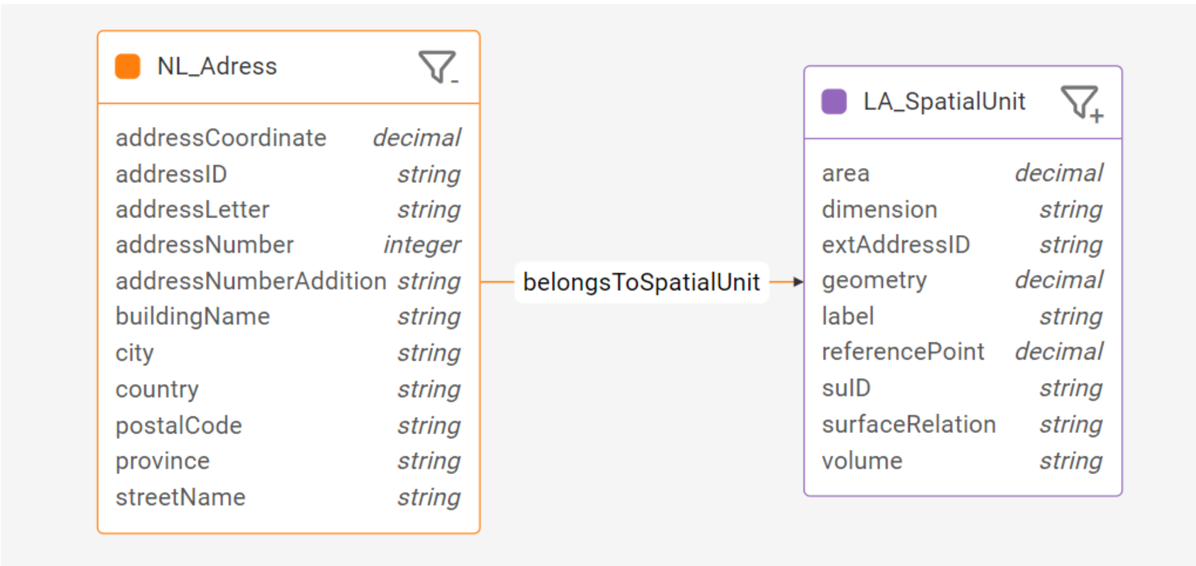

Figure B.7: Class NL_Address

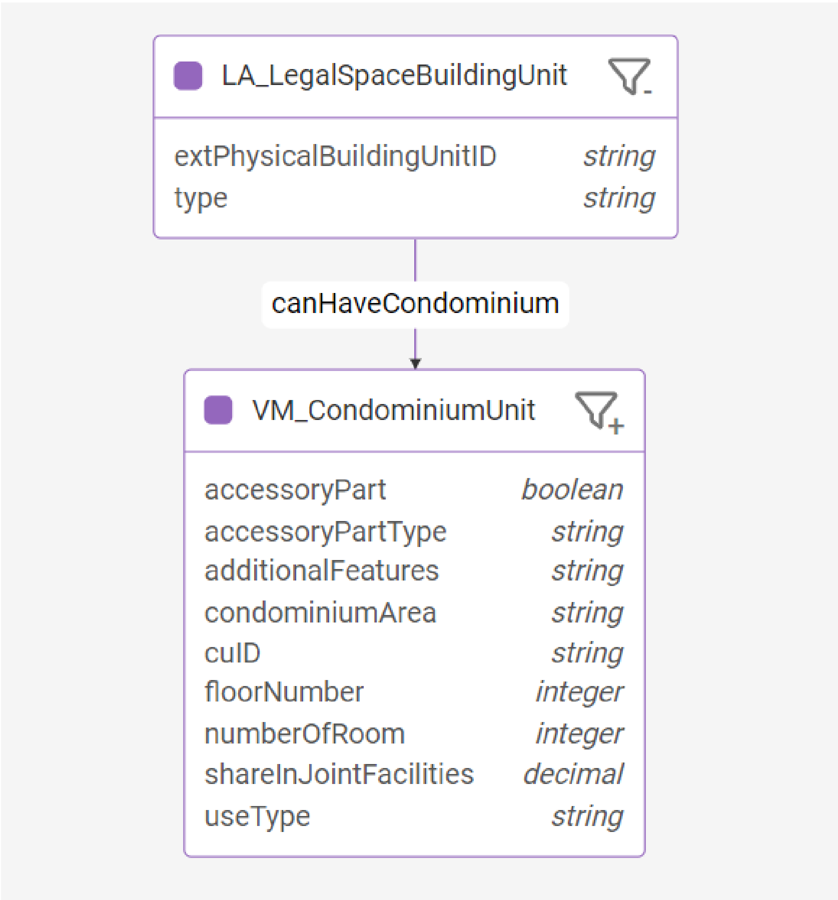

Figure B.8: Class LA_LegalSpaceBuildingUnit

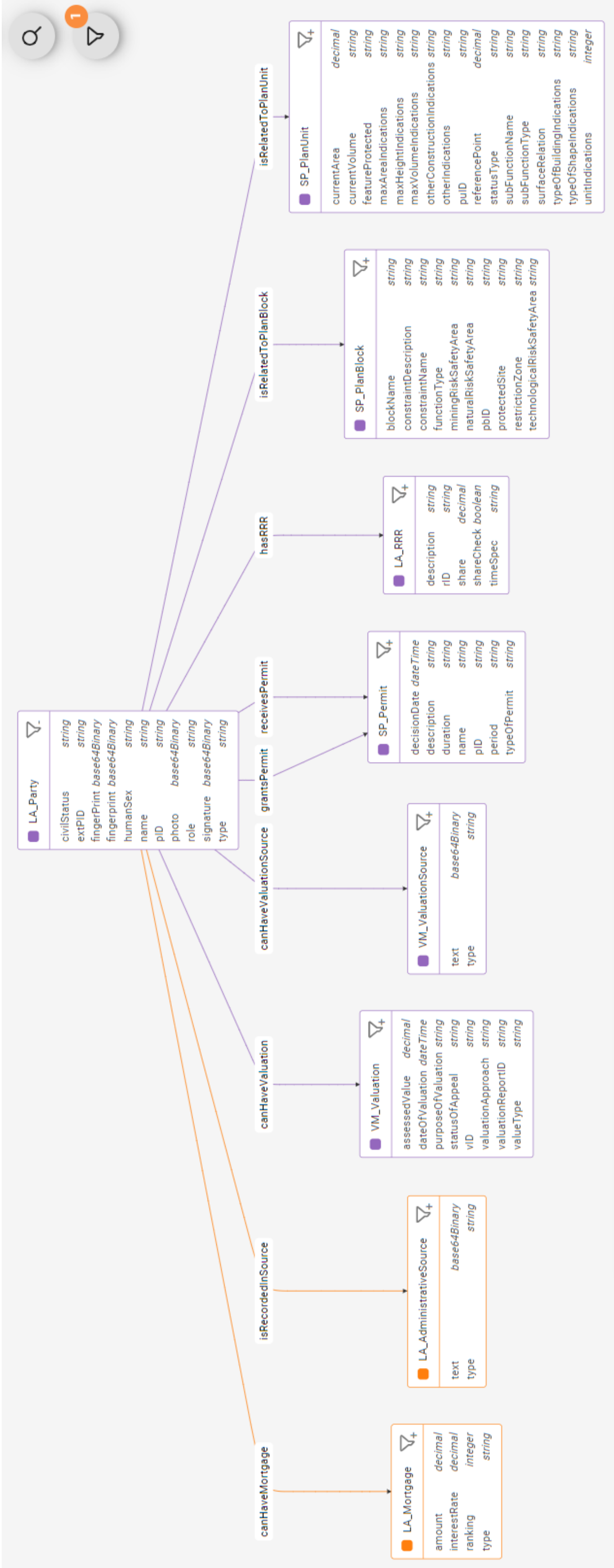

Figure B.9: Class LA_Party

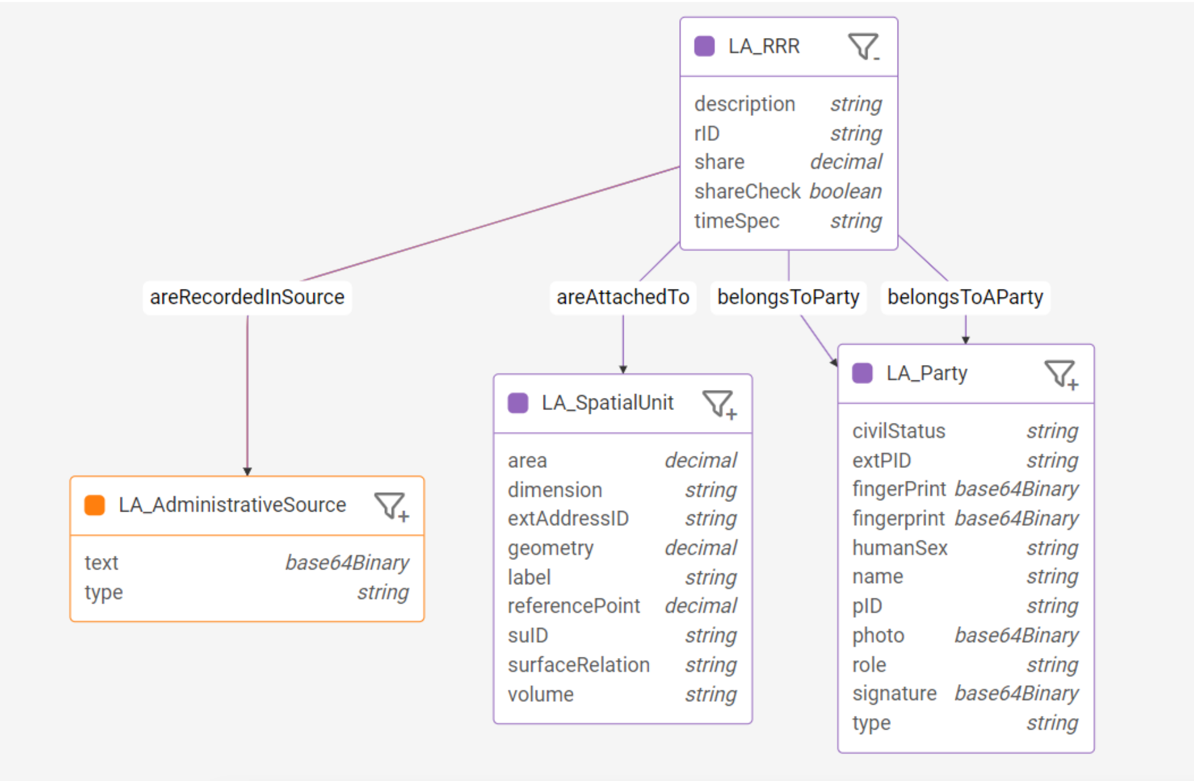

Figure B.10: Class LA_RRR

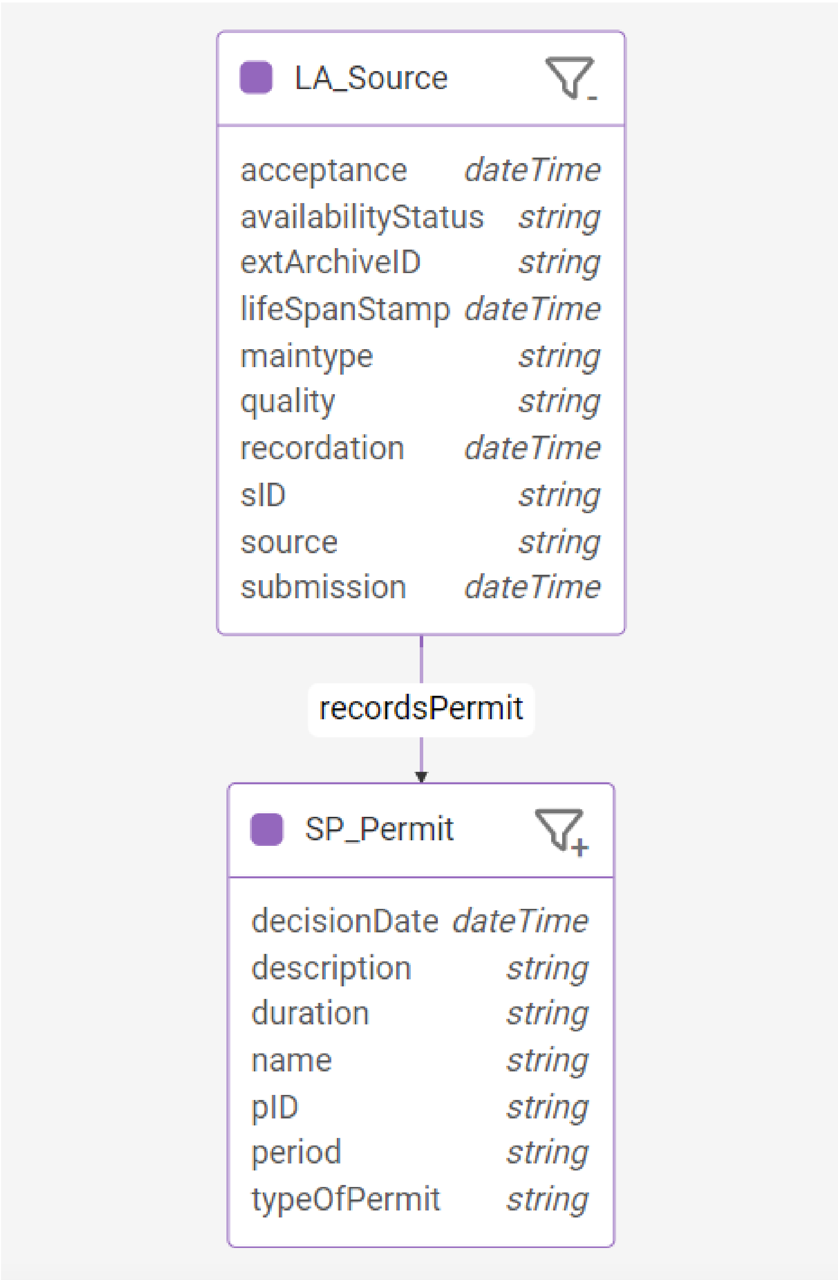

Figure B.11: Class LA_Source

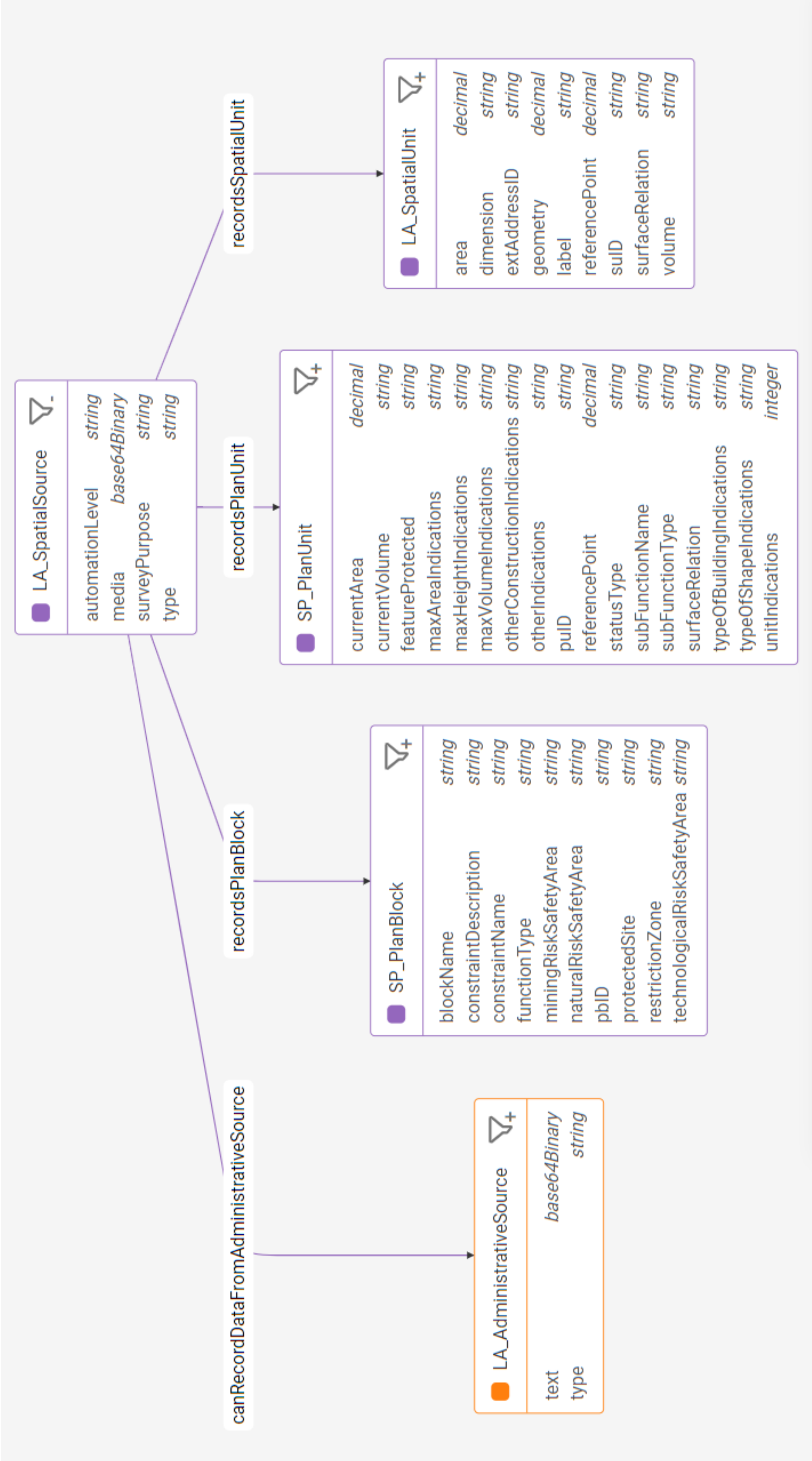

Figure B.12: Class LA_SpatialSource

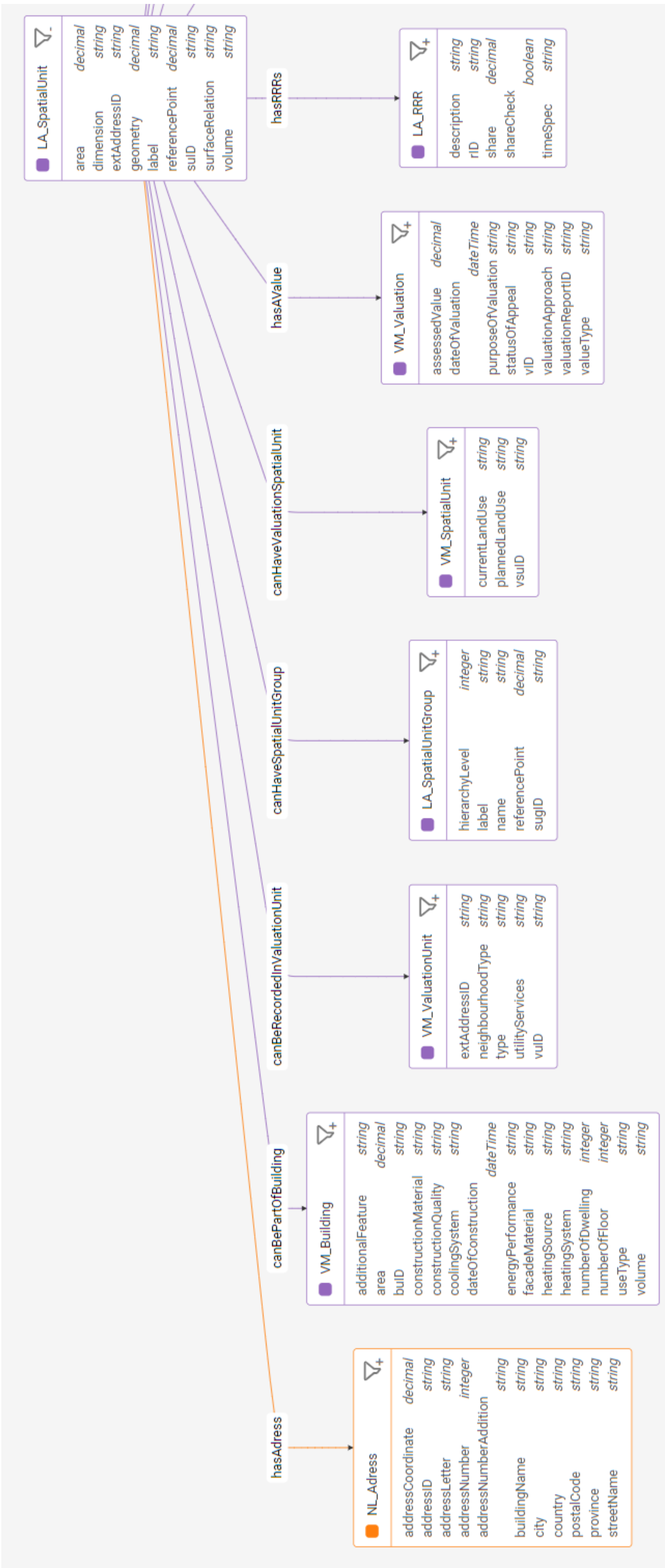

Figure B.13: Class LA_SpatialUnit - part 1

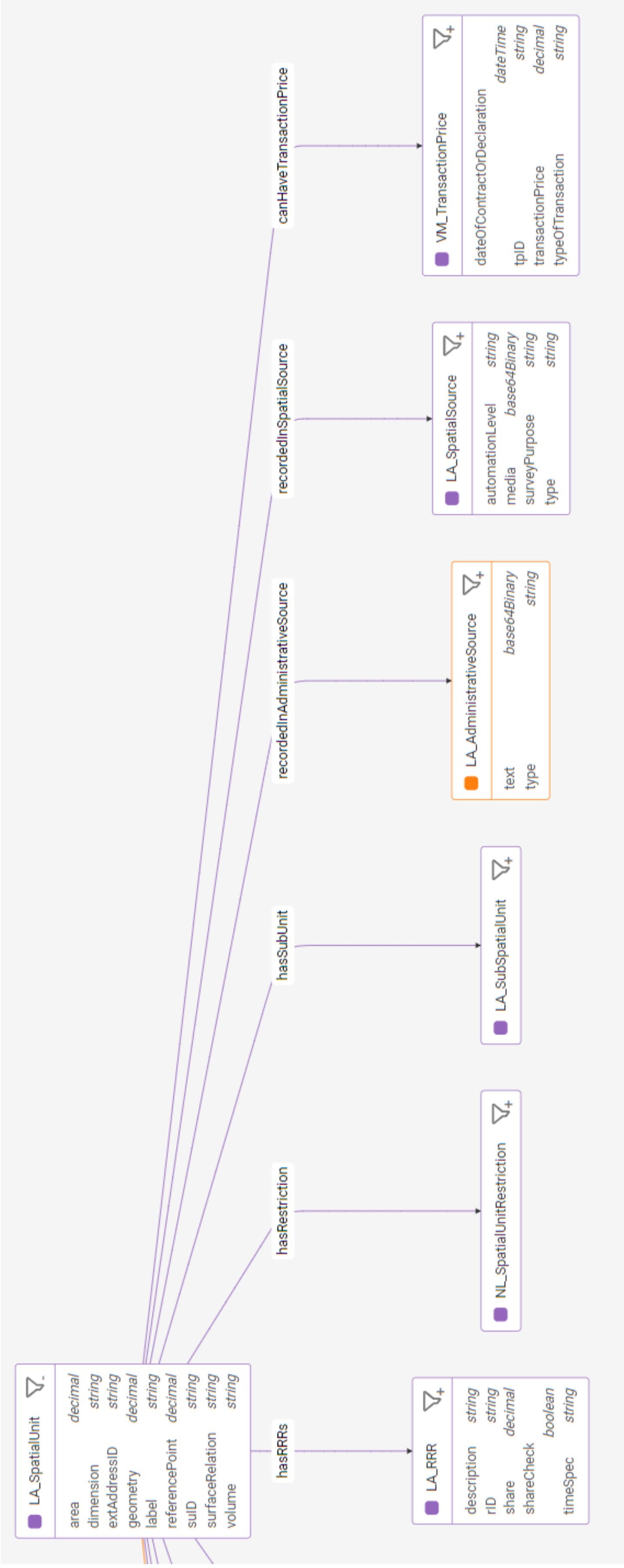

Figure B.14: Class LA_SpatialUnit - part 2

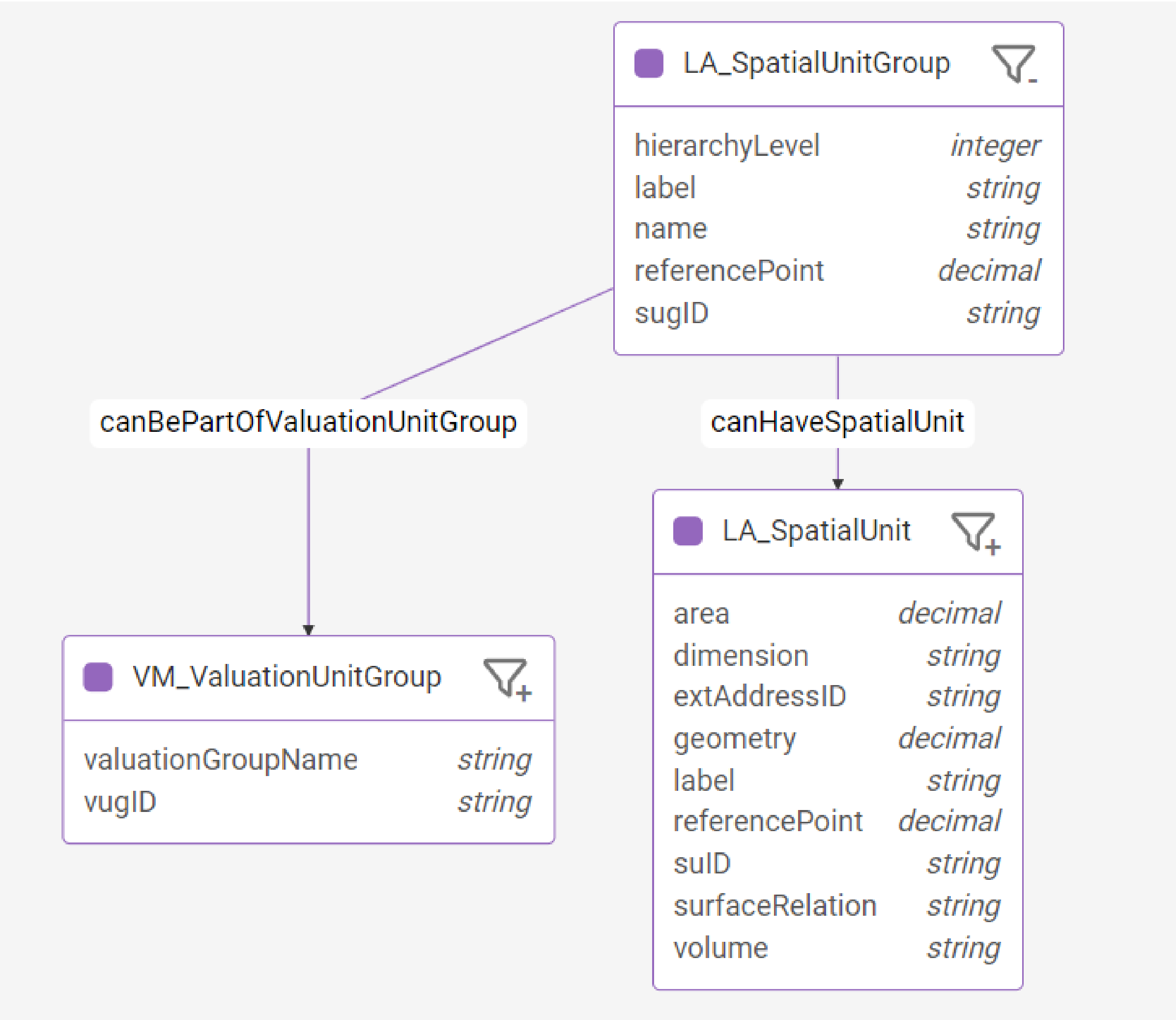

Figure B.15: Class LA_SpatialUnitGroup

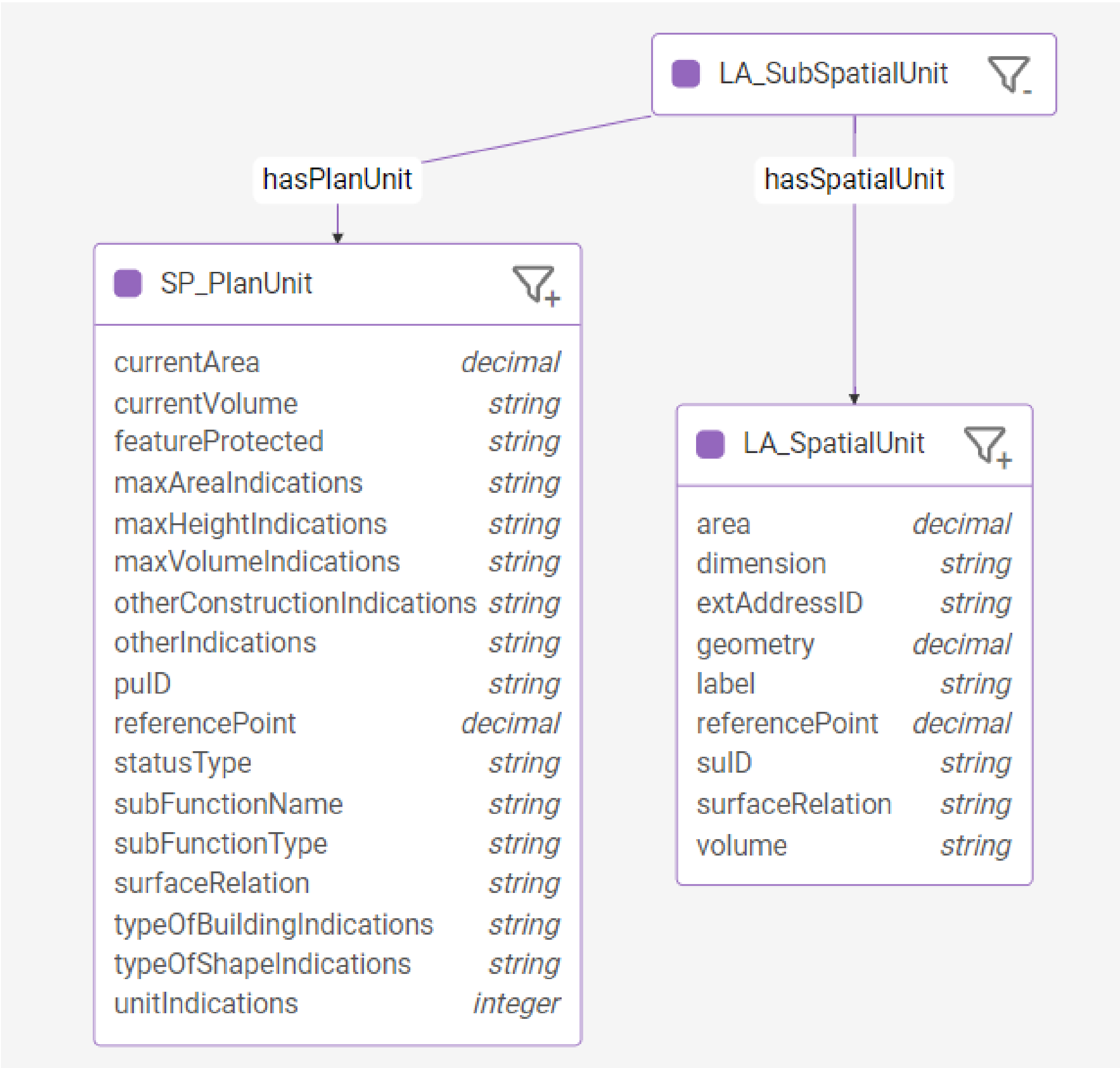

Figure B.16: Class LA_SubSpatialUnit

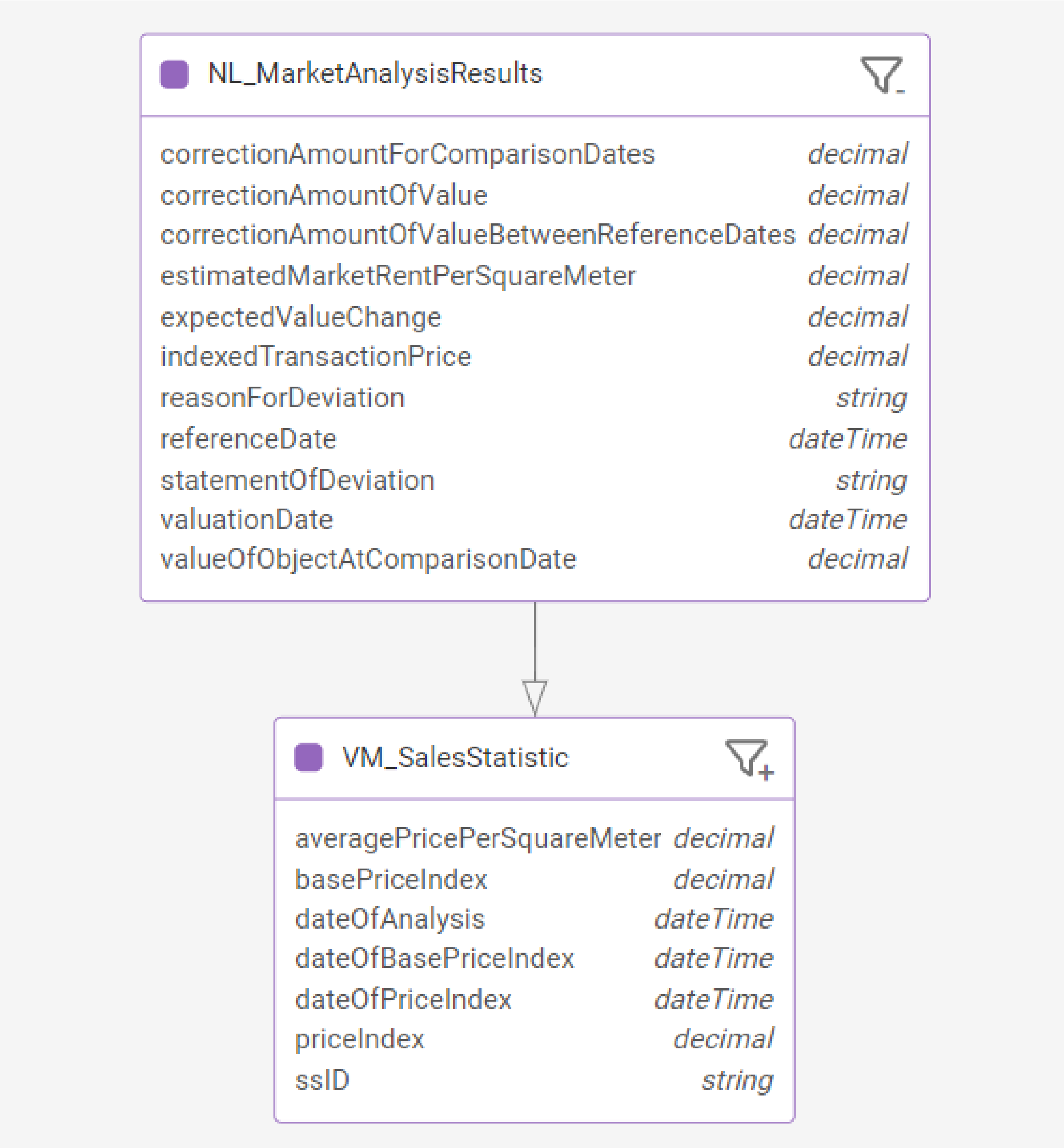

Figure B.17: Class NL_MarketAnalysisResults

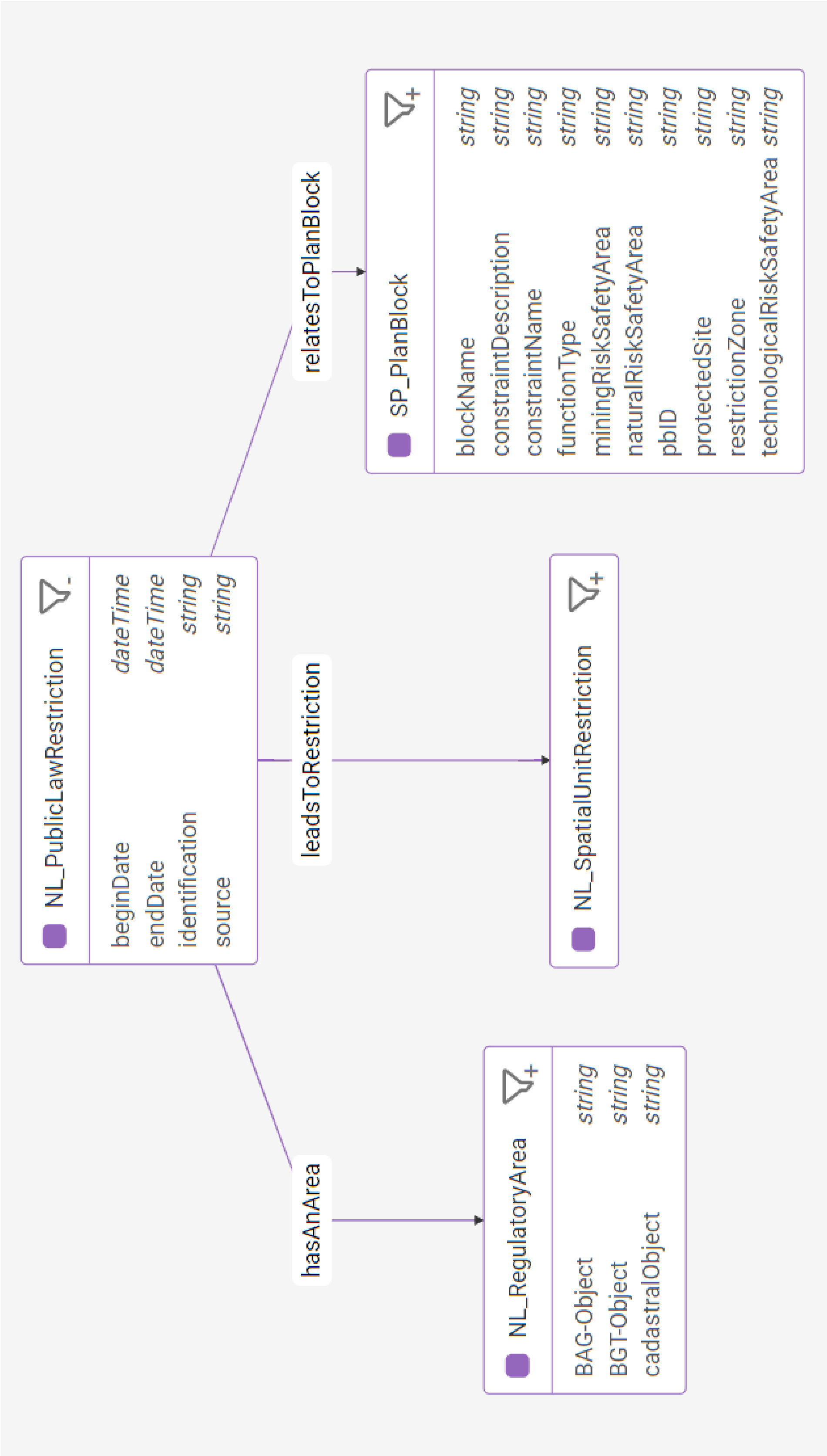

Figure B.18: Class NL_PublicLawRestriction

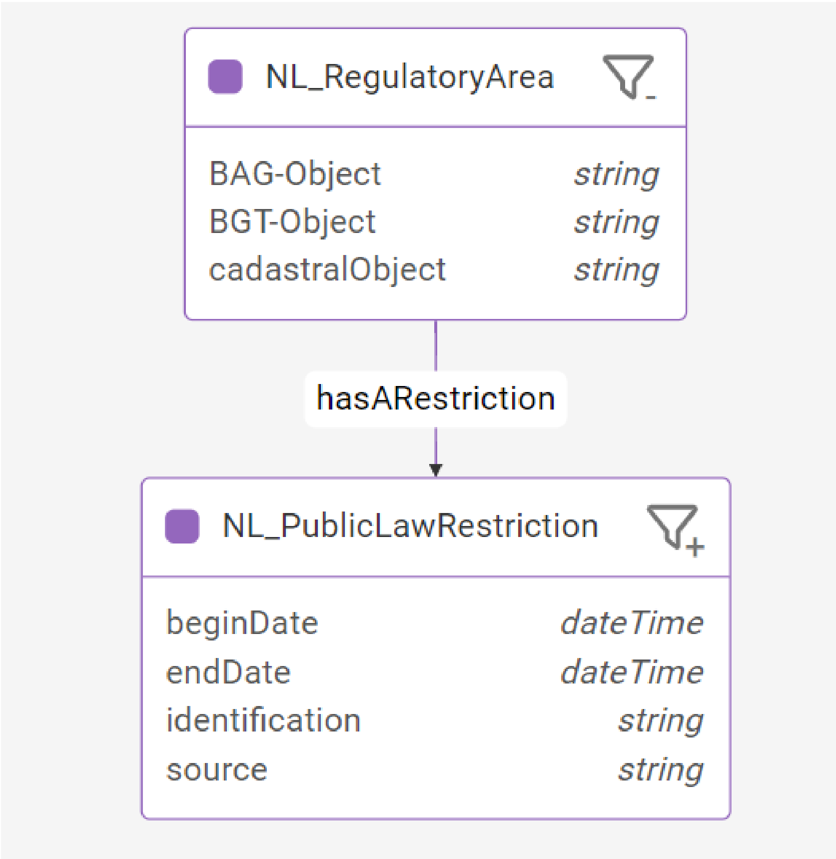

Figure B.19: Class NL_RegulatoryArea

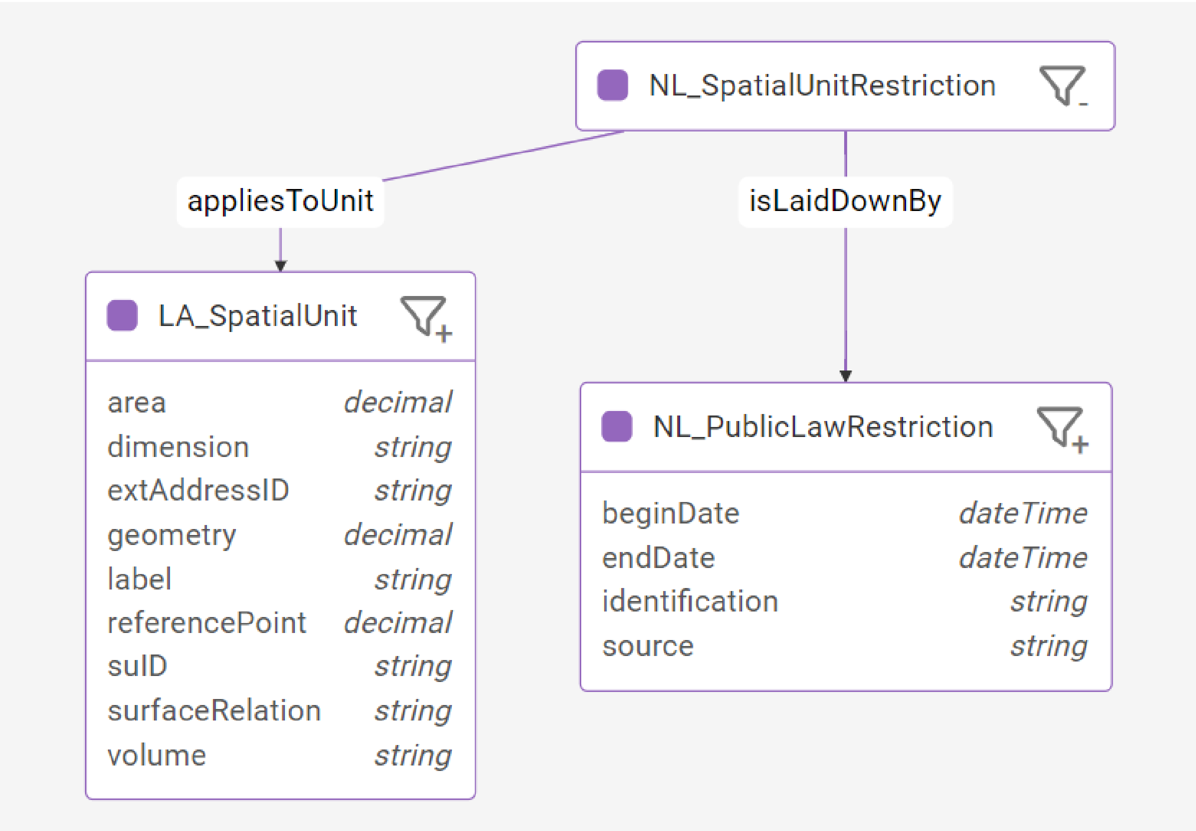

Figure B.20: Class NL_SpatialUnitRestriction

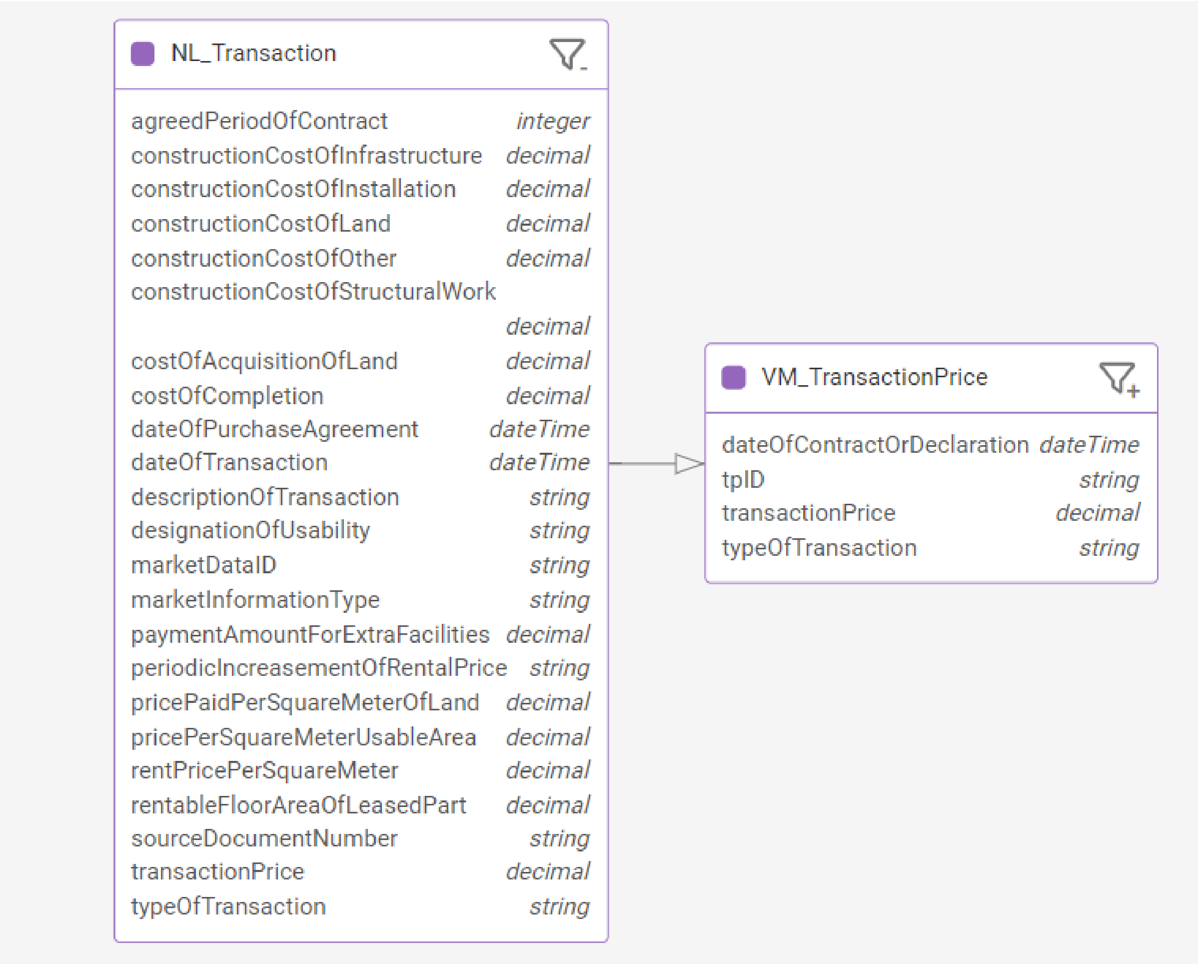

Figure B.21: Class NL_Transaction

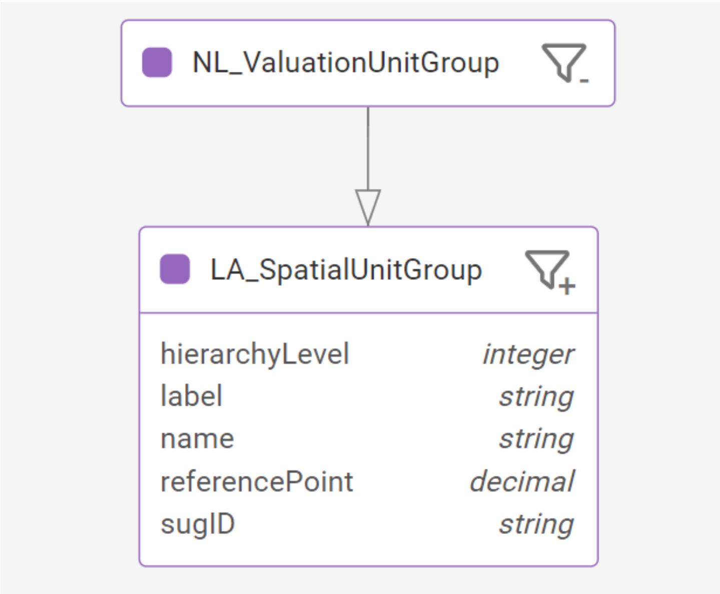

Figure B.22: Class NL_ValuationUnitGroup

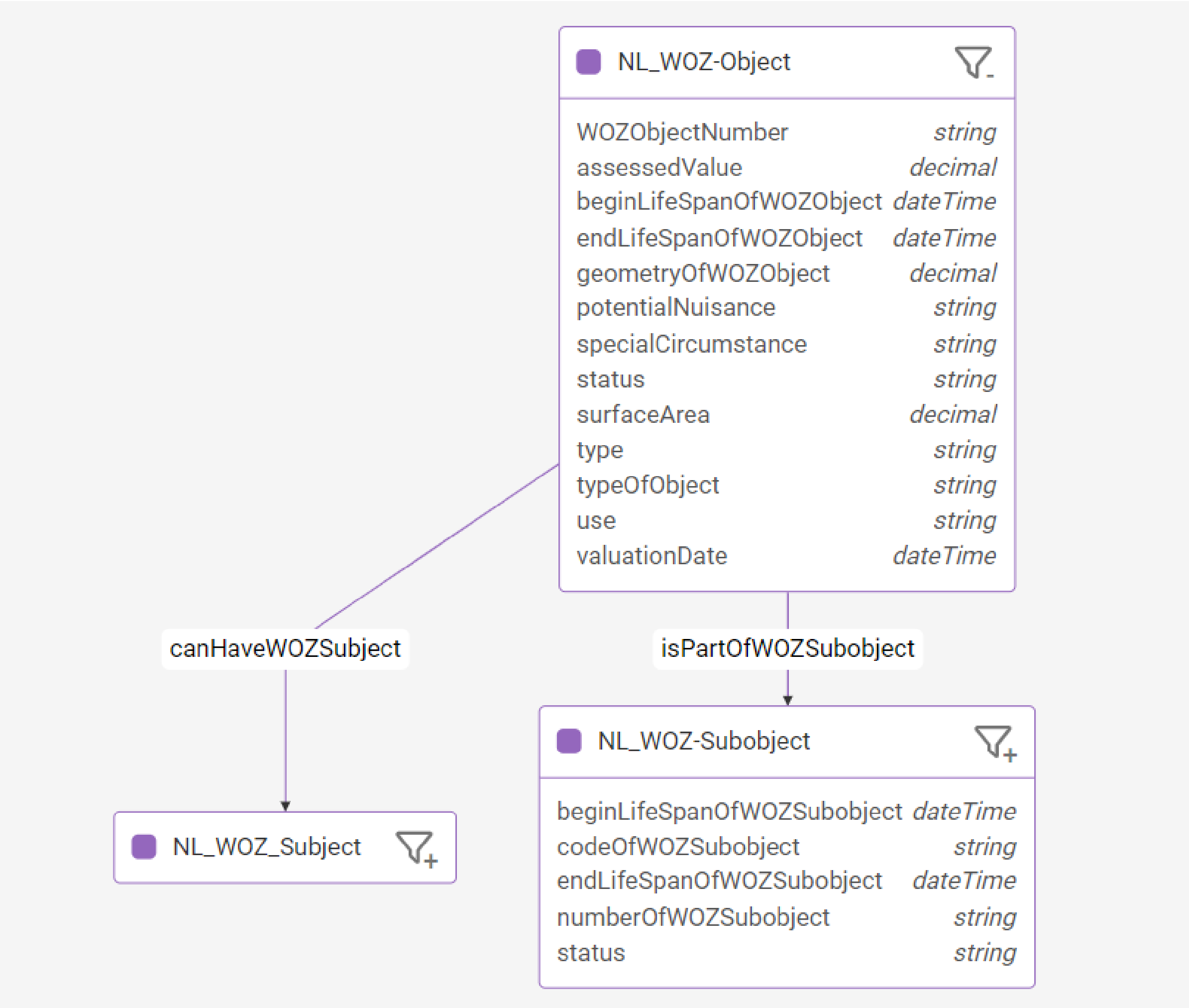

Figure B.23: Class NL_WOZ-Object

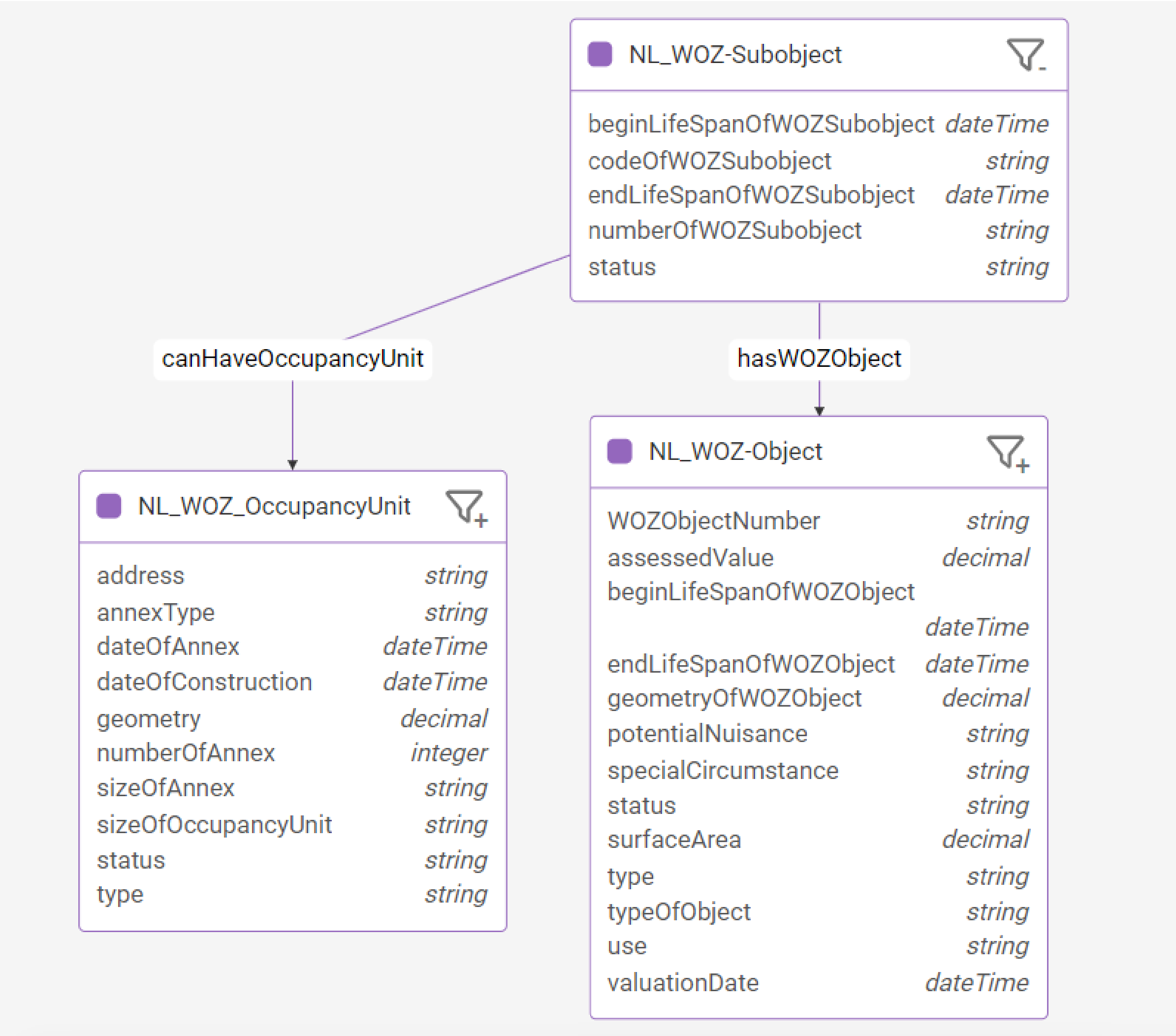

Figure B.24: Class NL_WOZ-Subobject

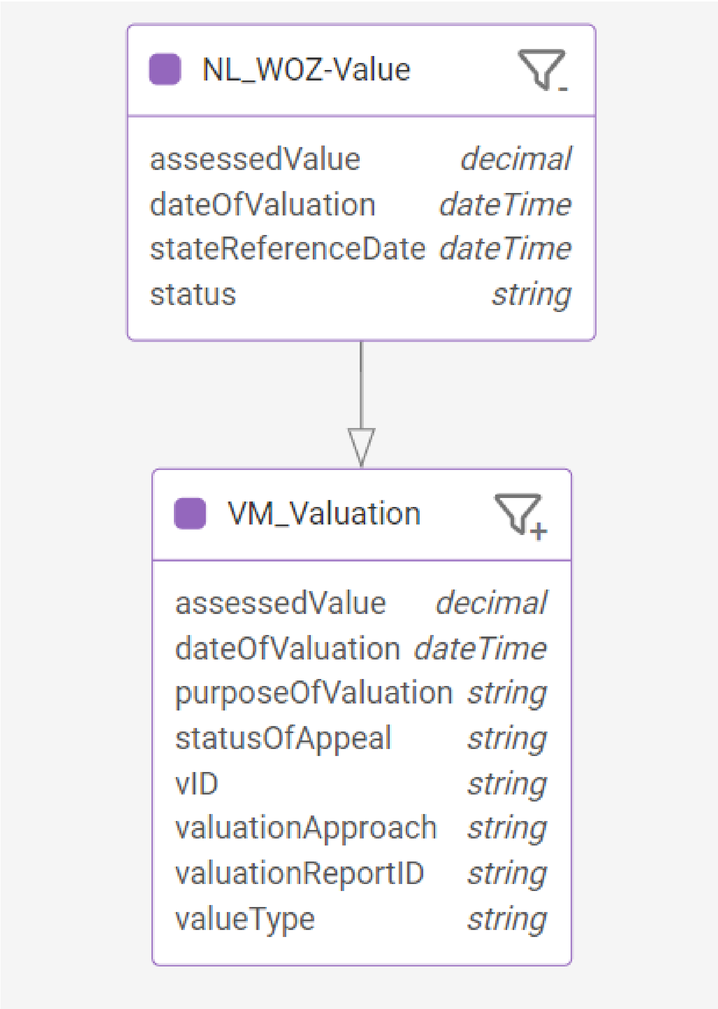

Figure B.25: Class NL_WOZ-Value

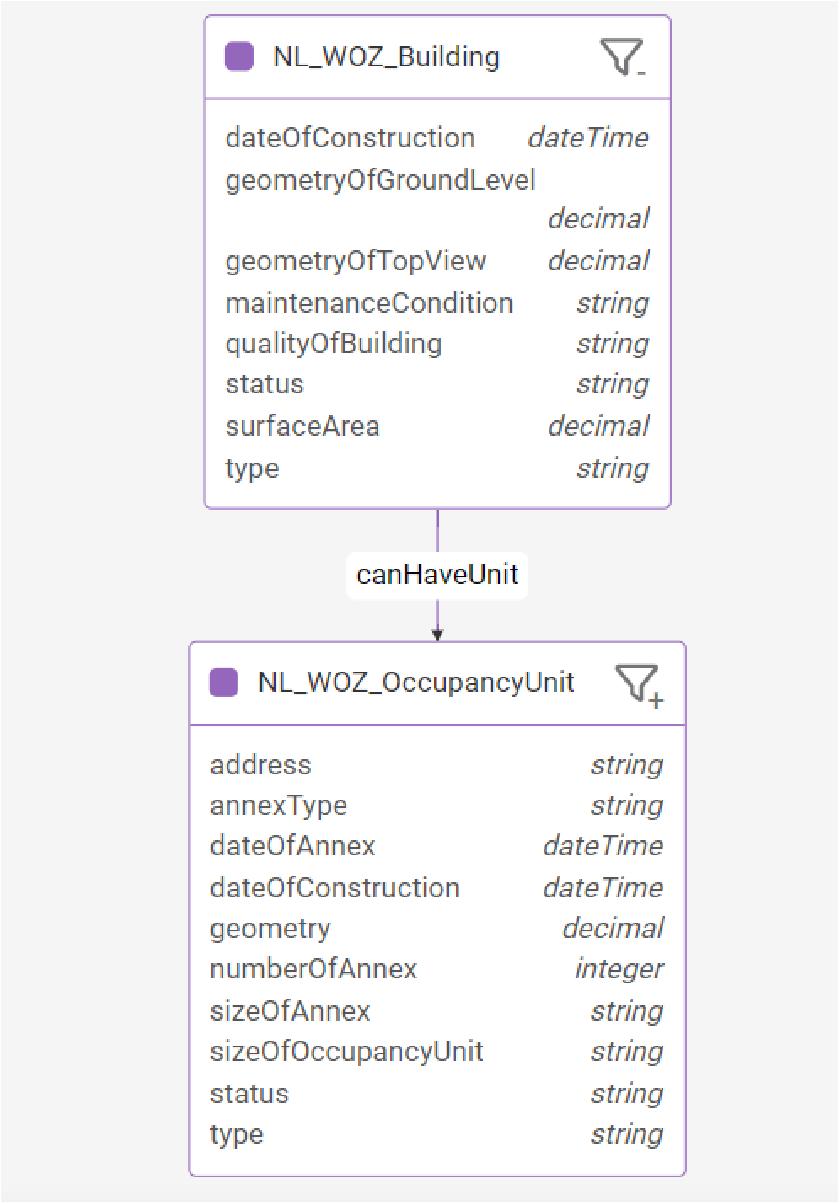

Figure B.26: Class NL_WOZ_Building

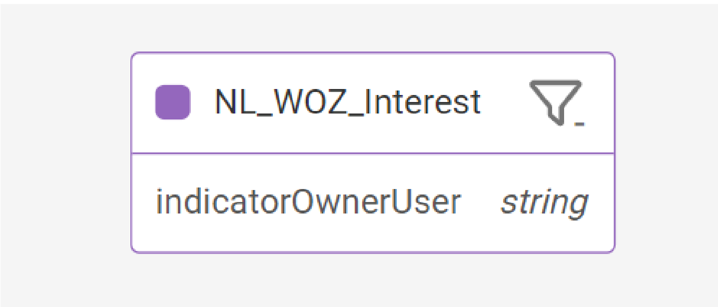

Figure B.27: Class NL_WOZ_Interest

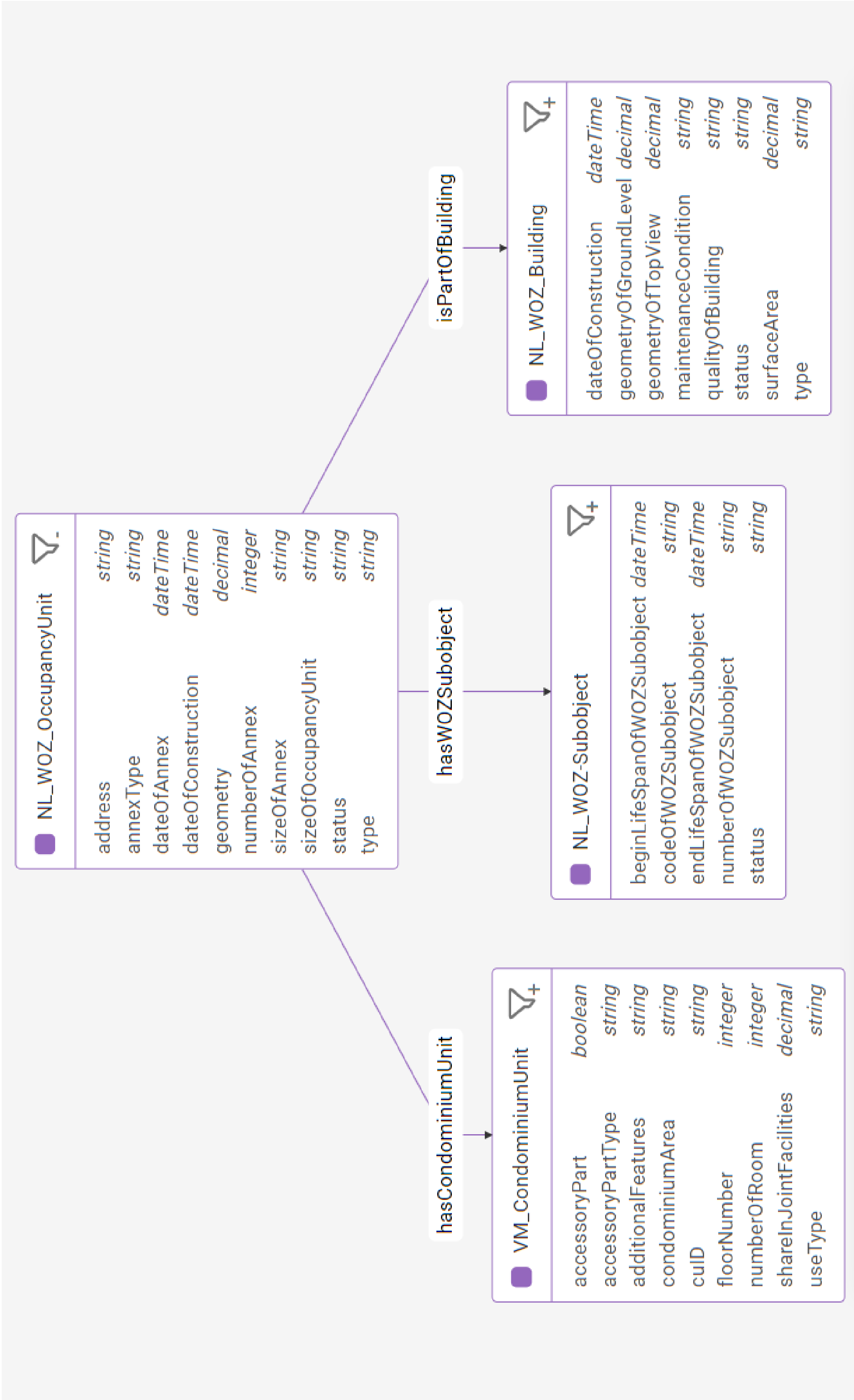

Figure B.28: Class NL_WOZ_OccupancyUnit

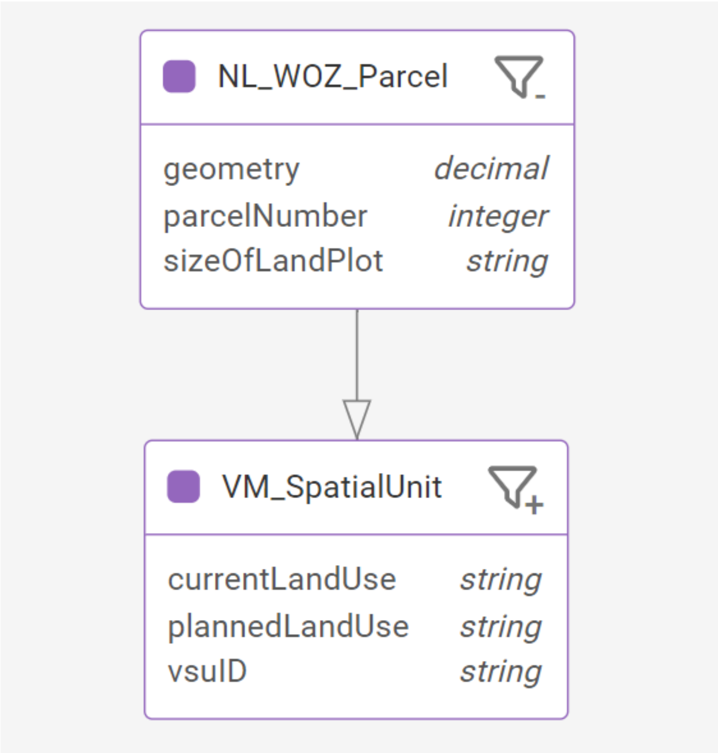

Figure B.29: Class NL_WOZ_Parcel

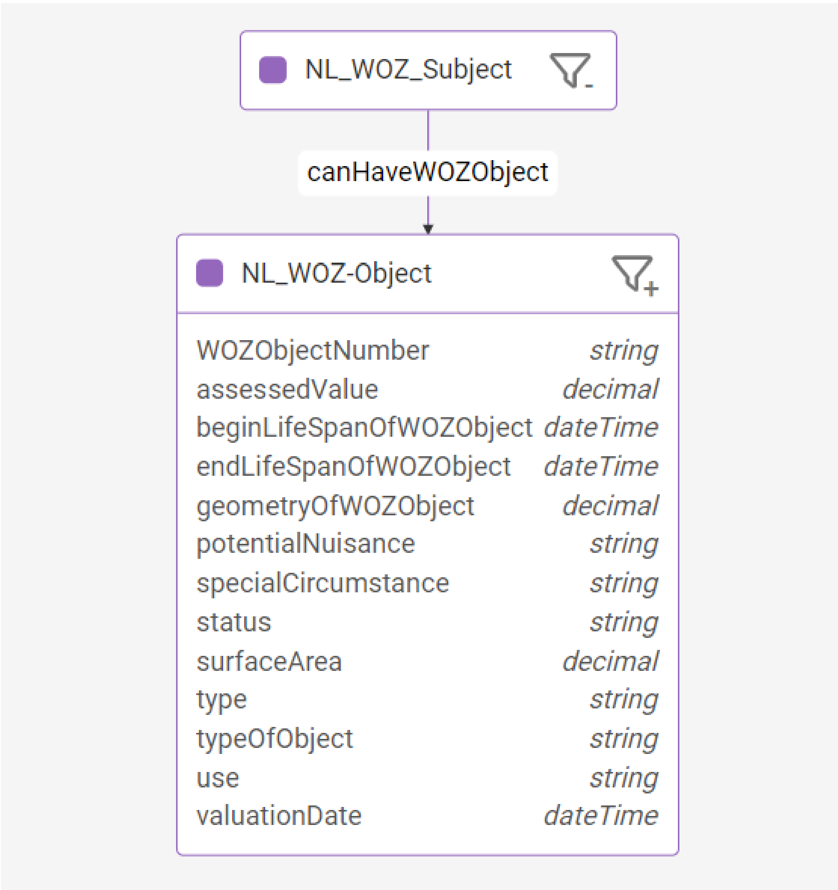

Figure B.30: Class NL_WOZ-Subject

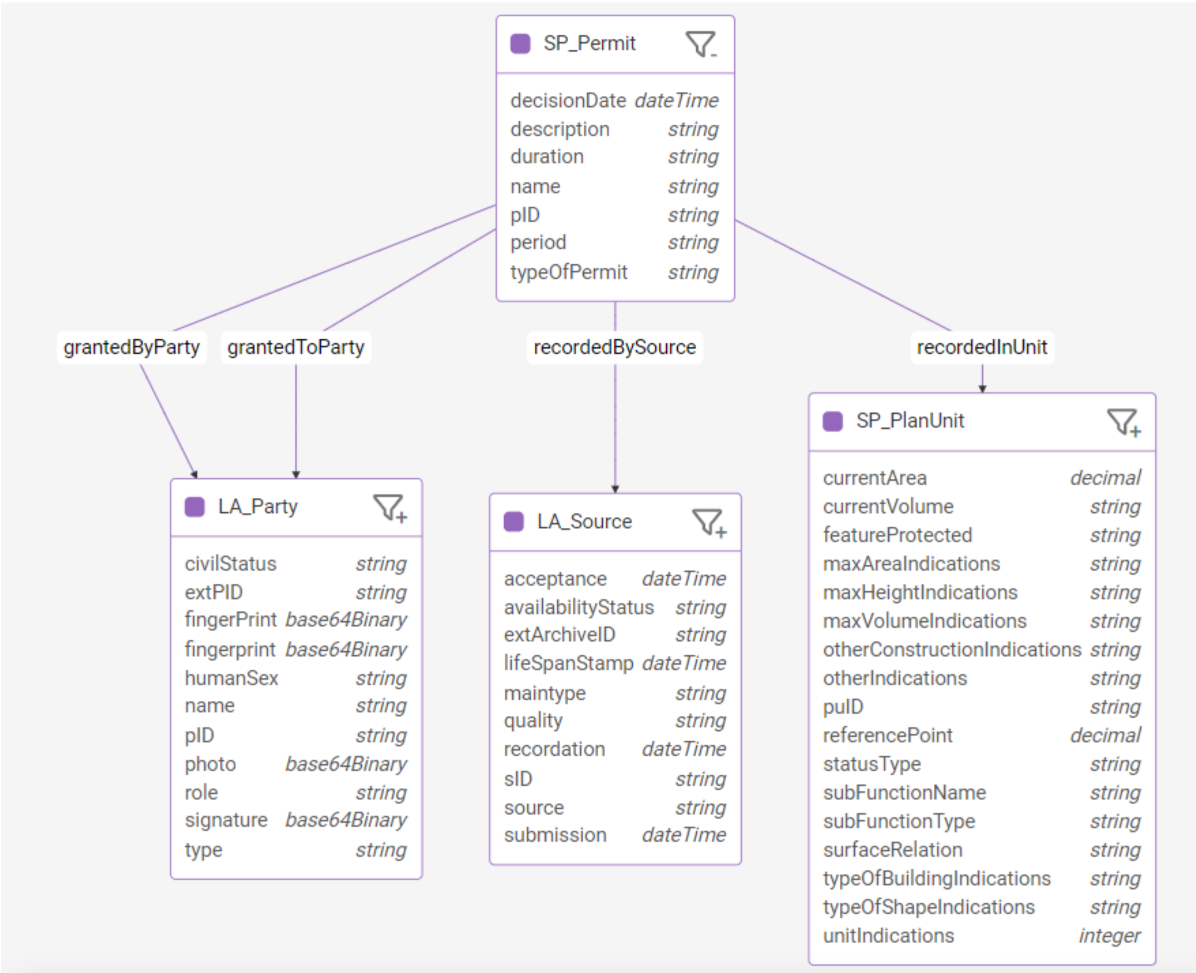

Figure B.31: Class SP_Permit

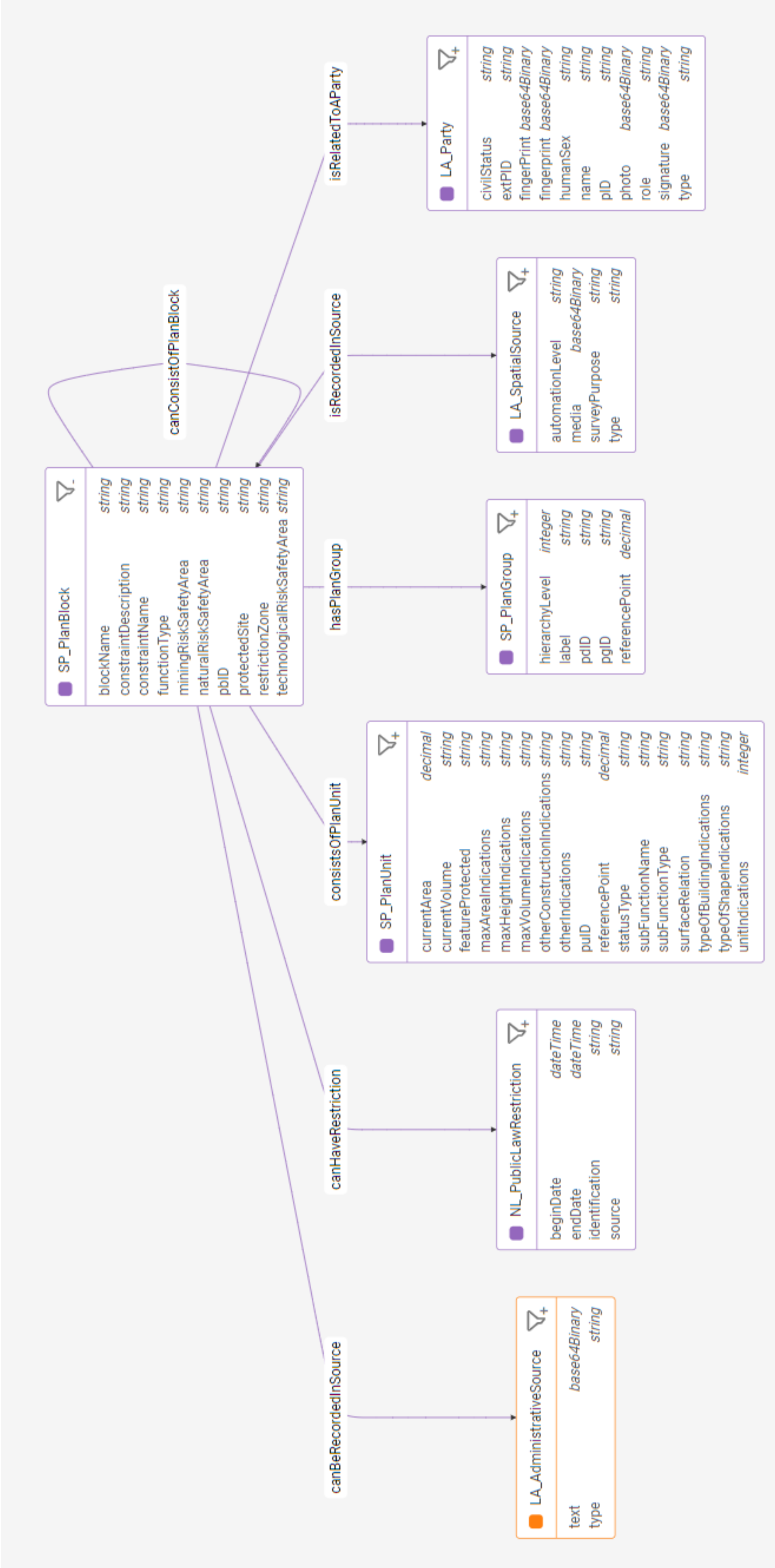

Figure B.32: Class SP_PlanBlock

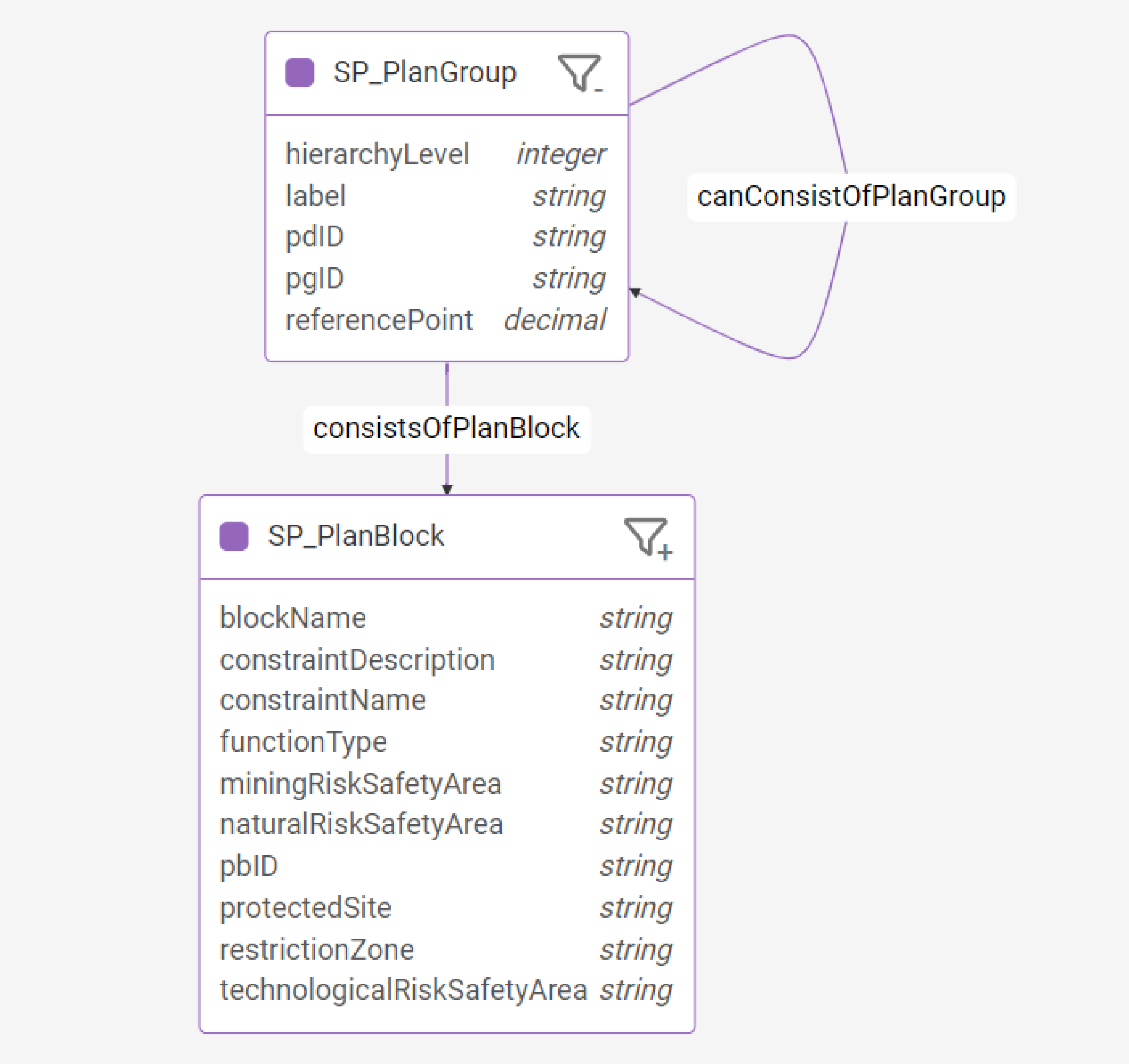

Figure B.33: Class SP_PlanGroup

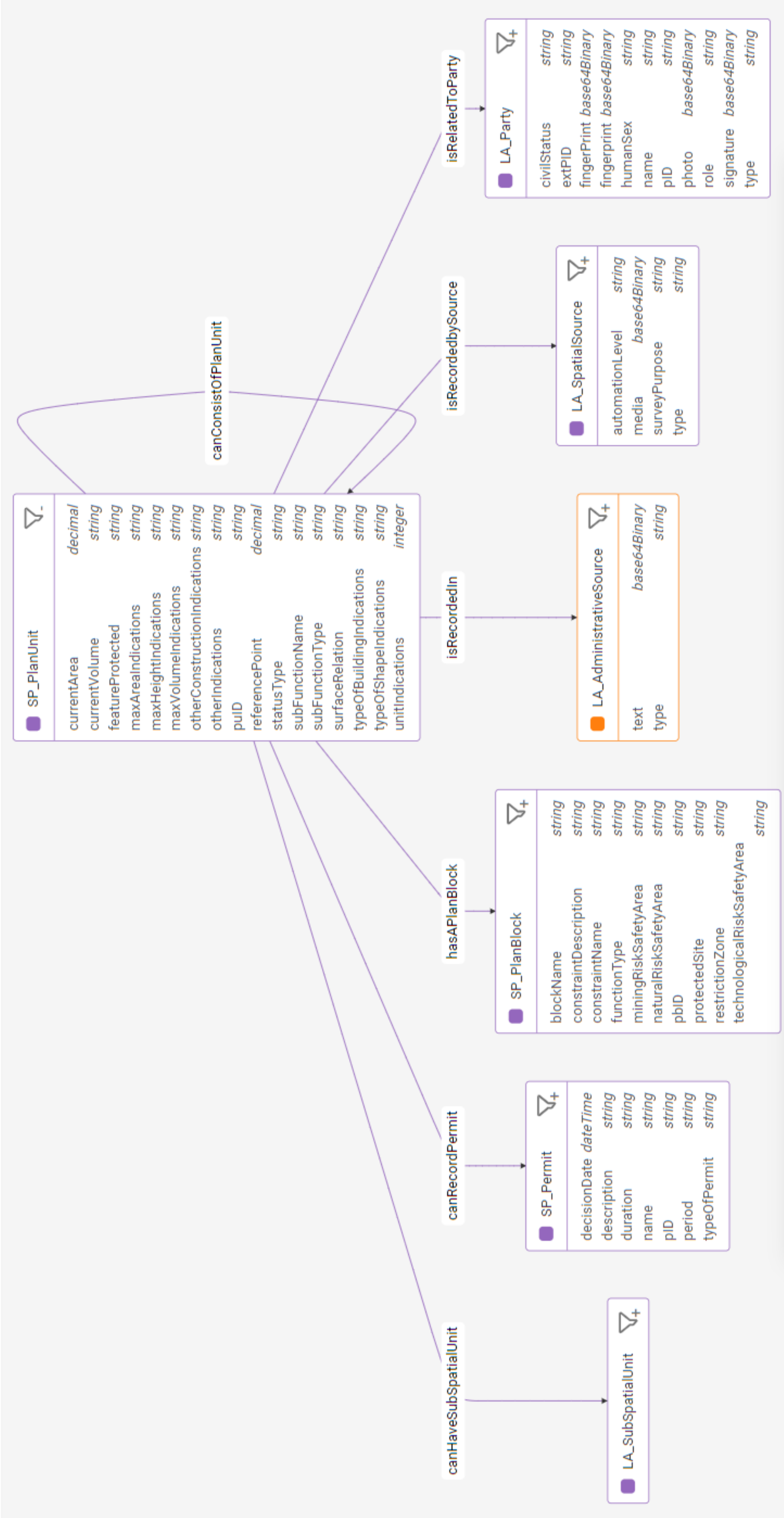

Figure B.34: Class SP_PlanUnit

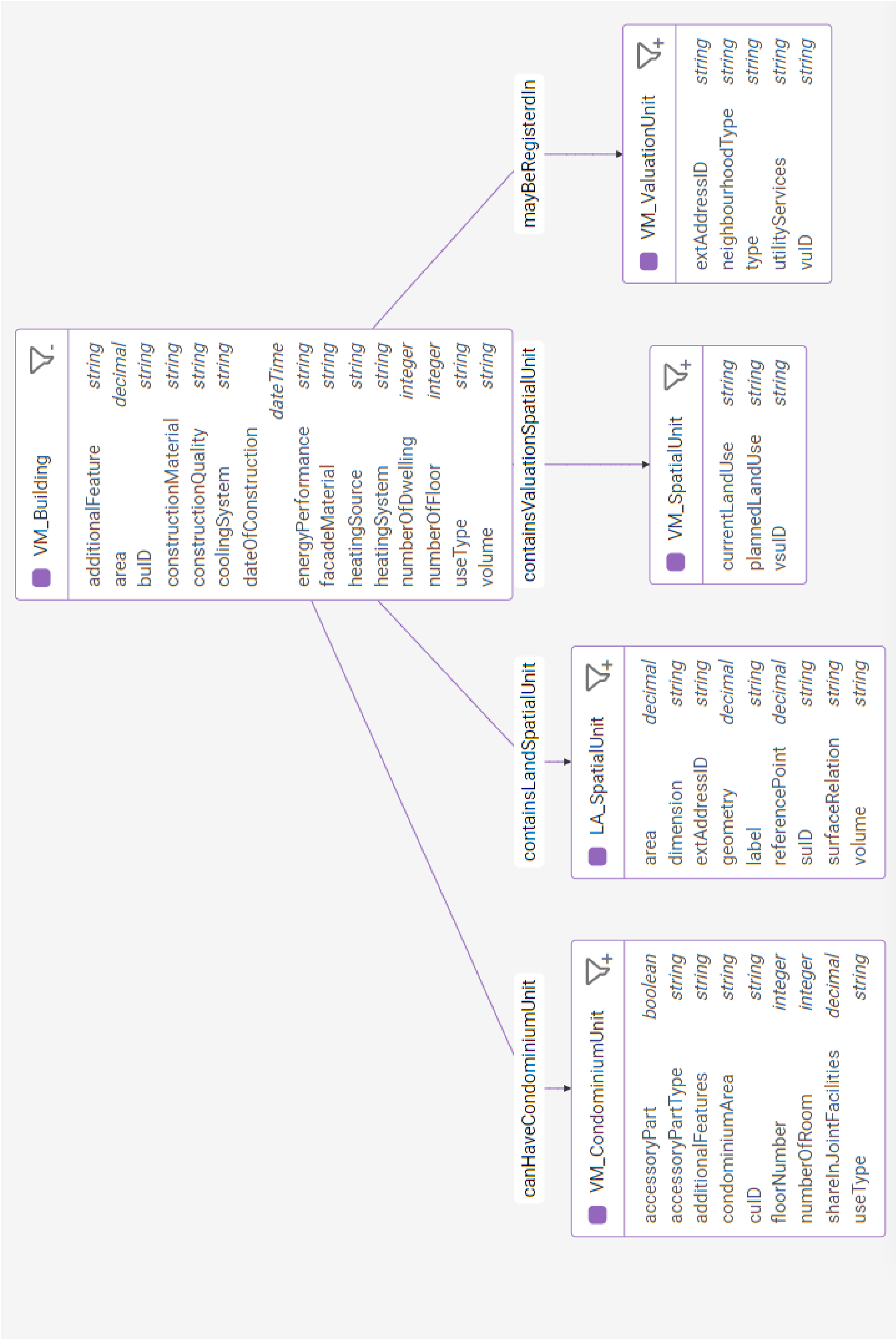

Figure B.35: Class VM_Building

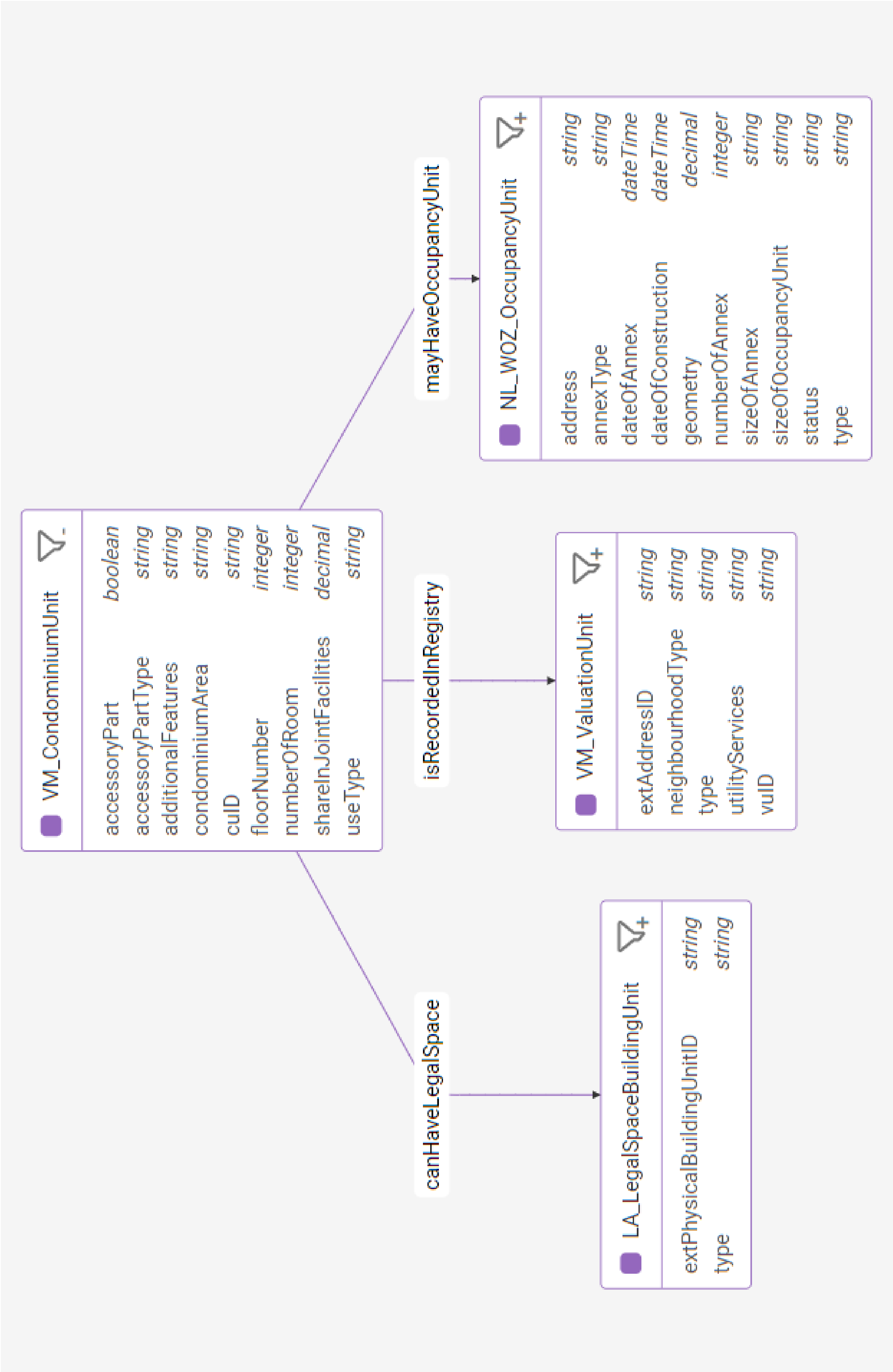

Figure B.36: Class VM_CondominiumUnit

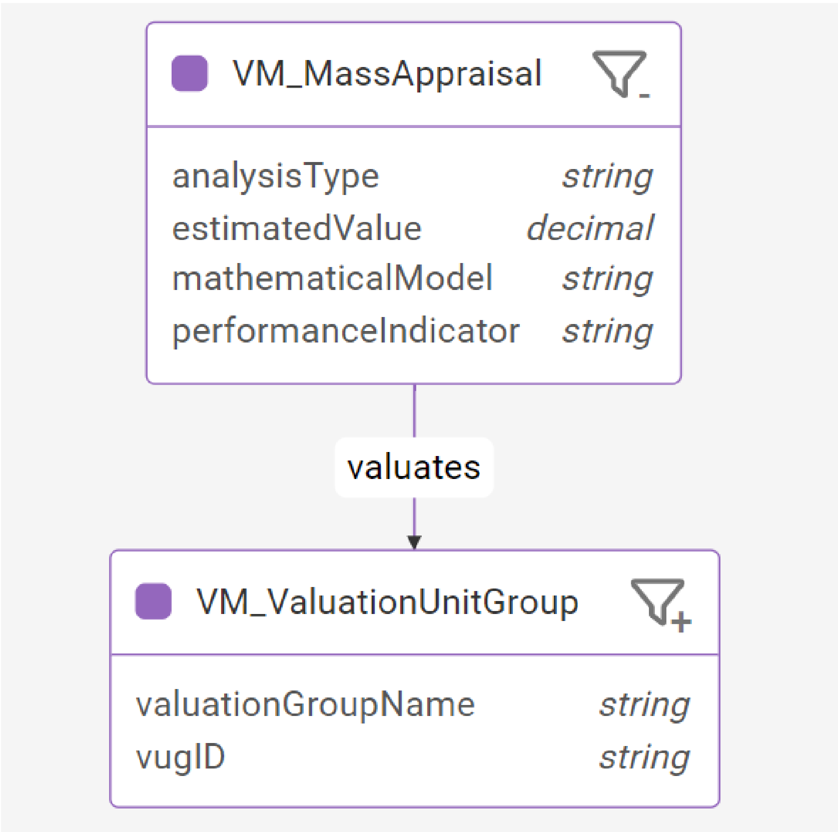

Figure B.37: Class VM_MassAppraisal

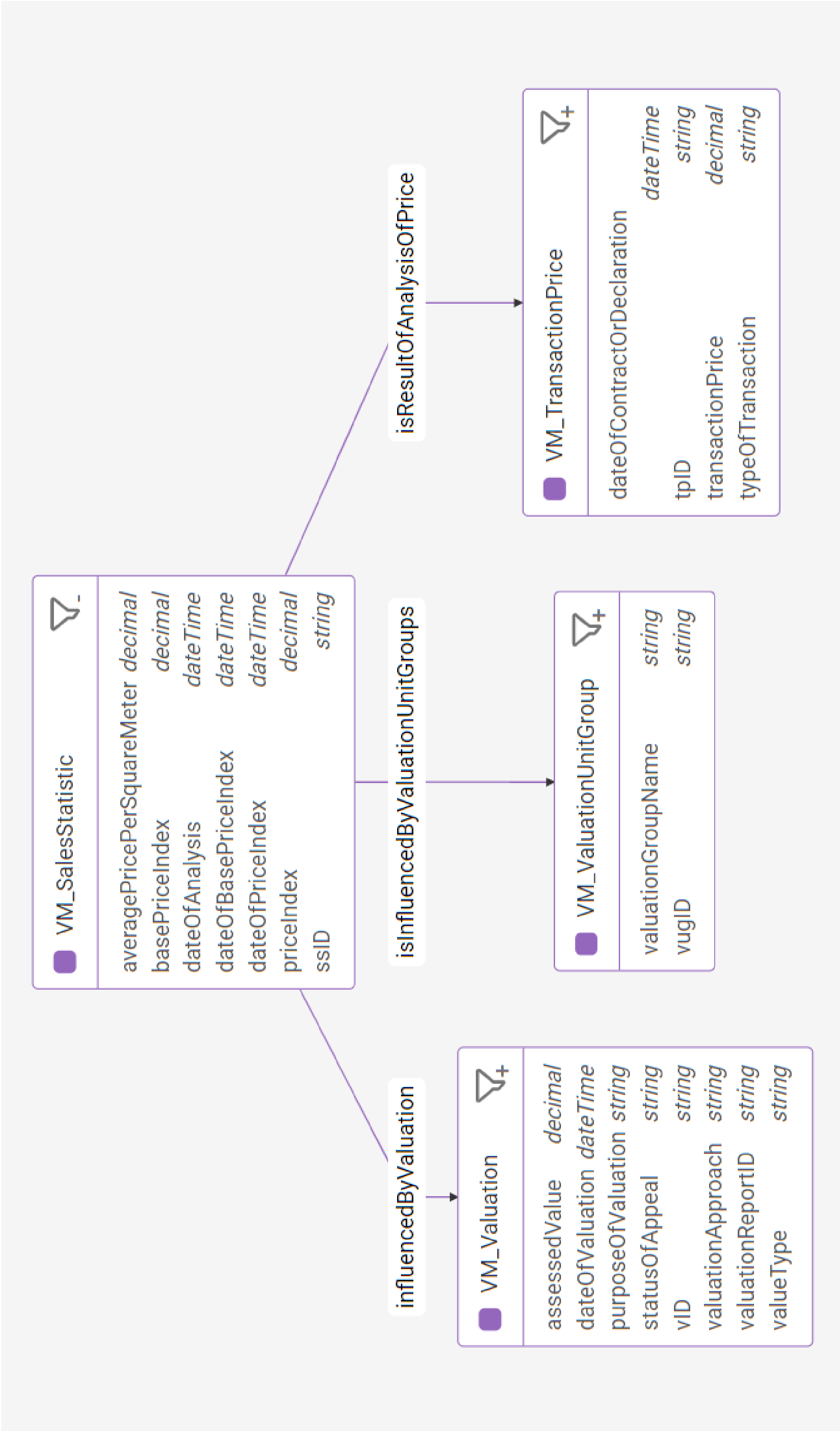

Figure B.38: Class VM_SalesStatistic

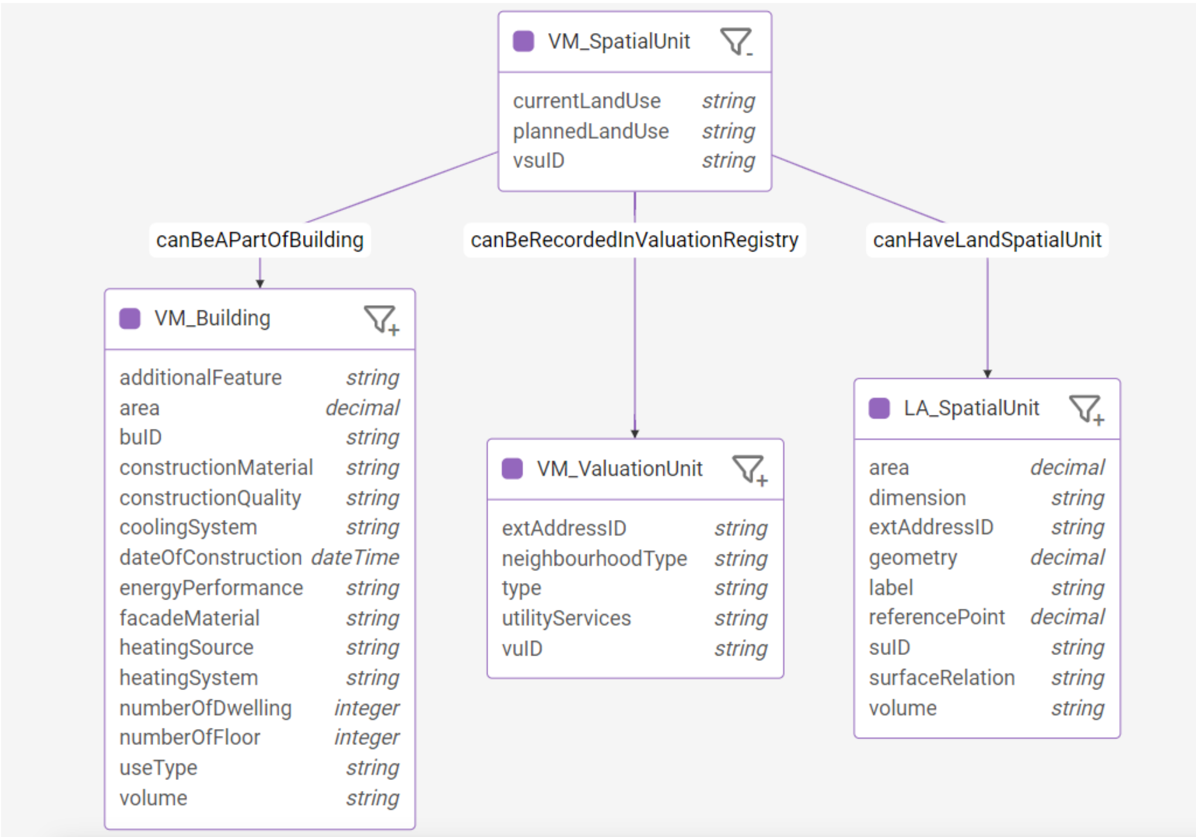

Figure B.39: Class VM_SpatialUnit

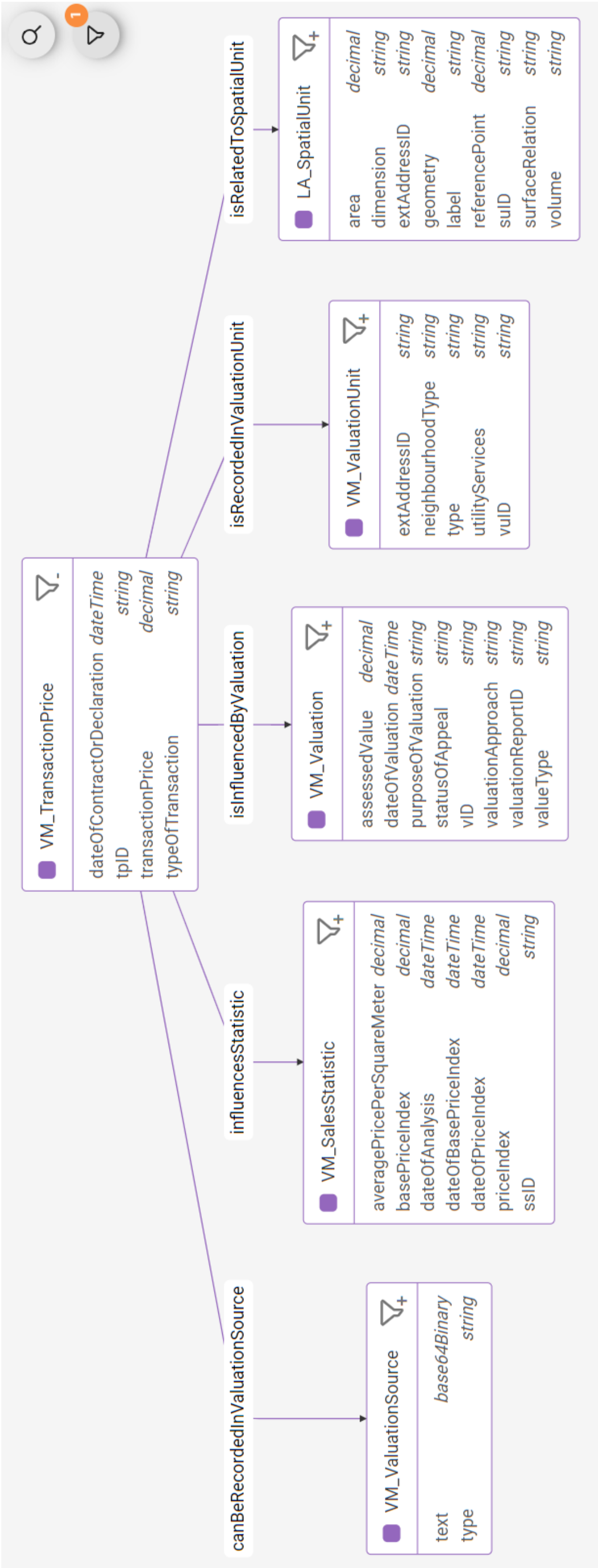

Figure B.40: Class VM_TransactionPrice

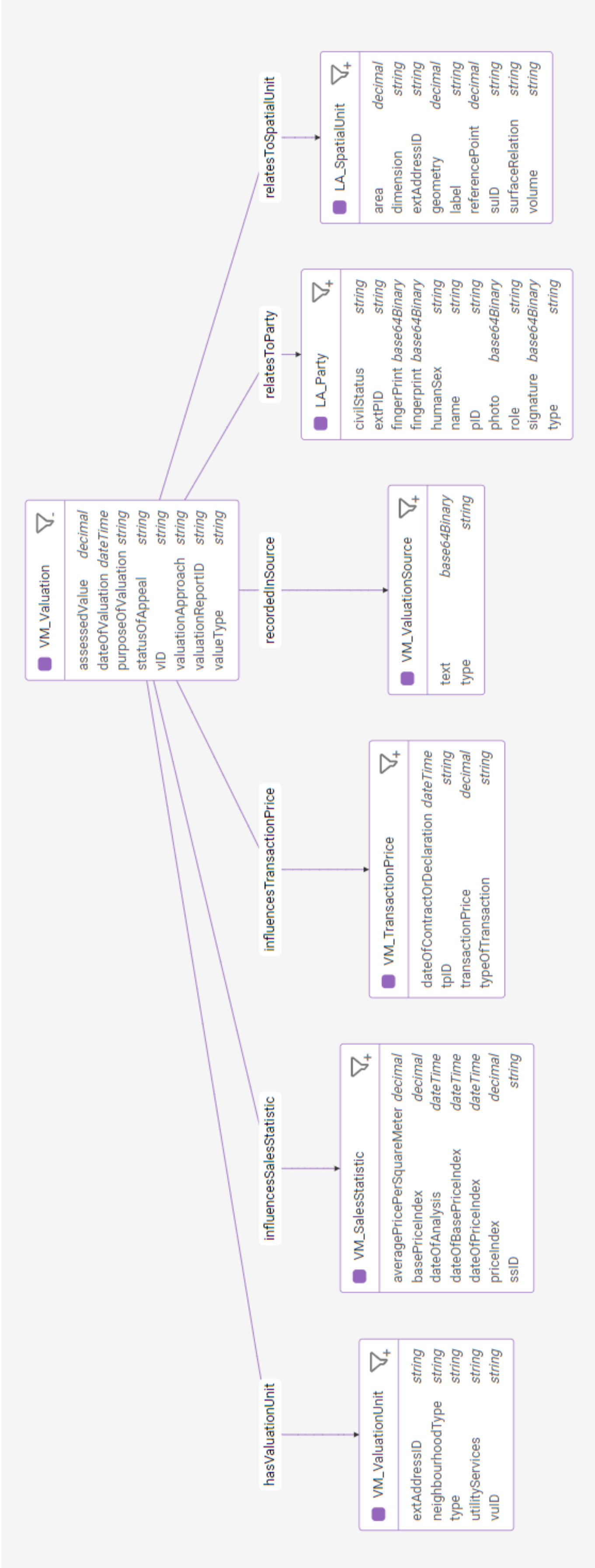

Figure B.41: Class VM_Valuation

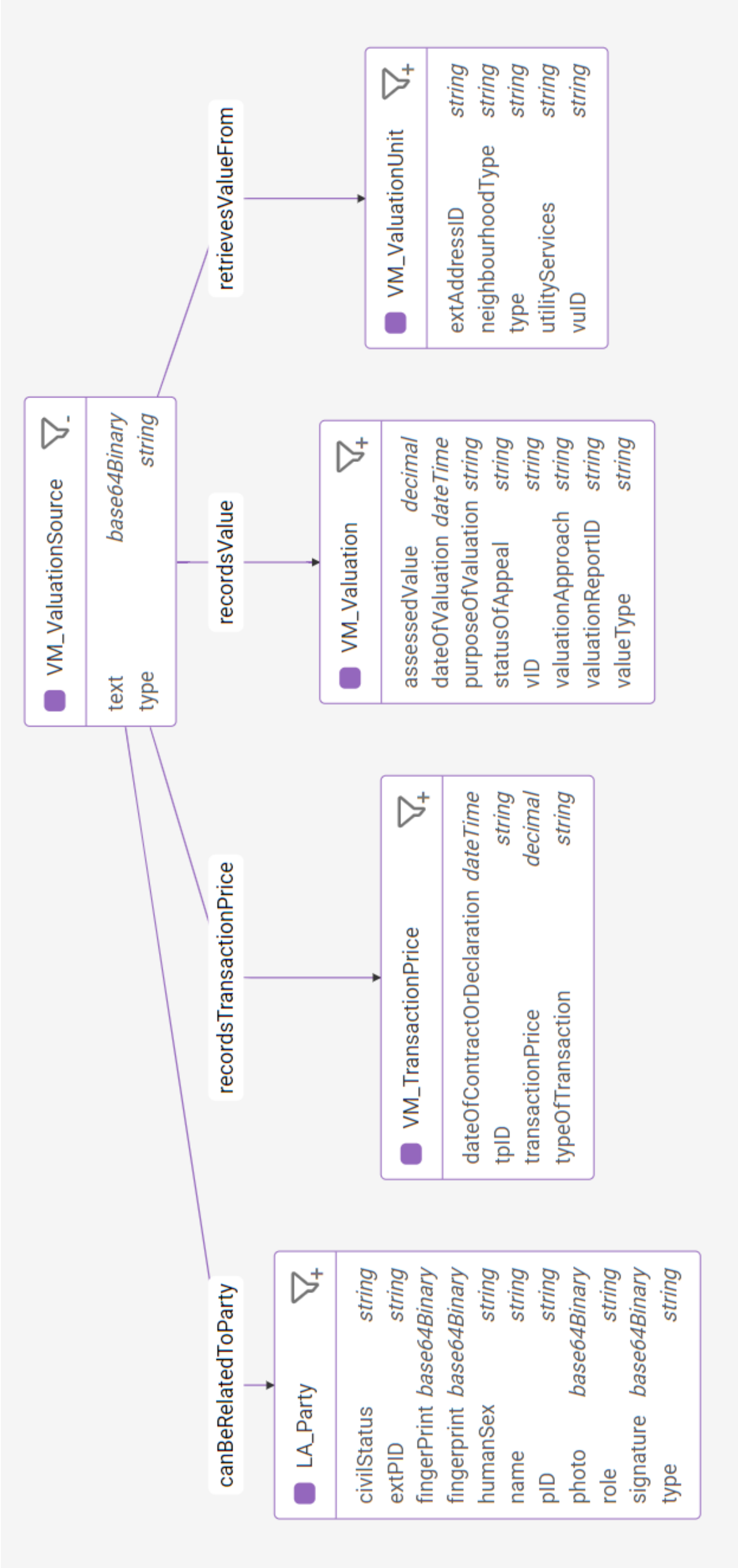

Figure B.42: Class VM_ValuationSource

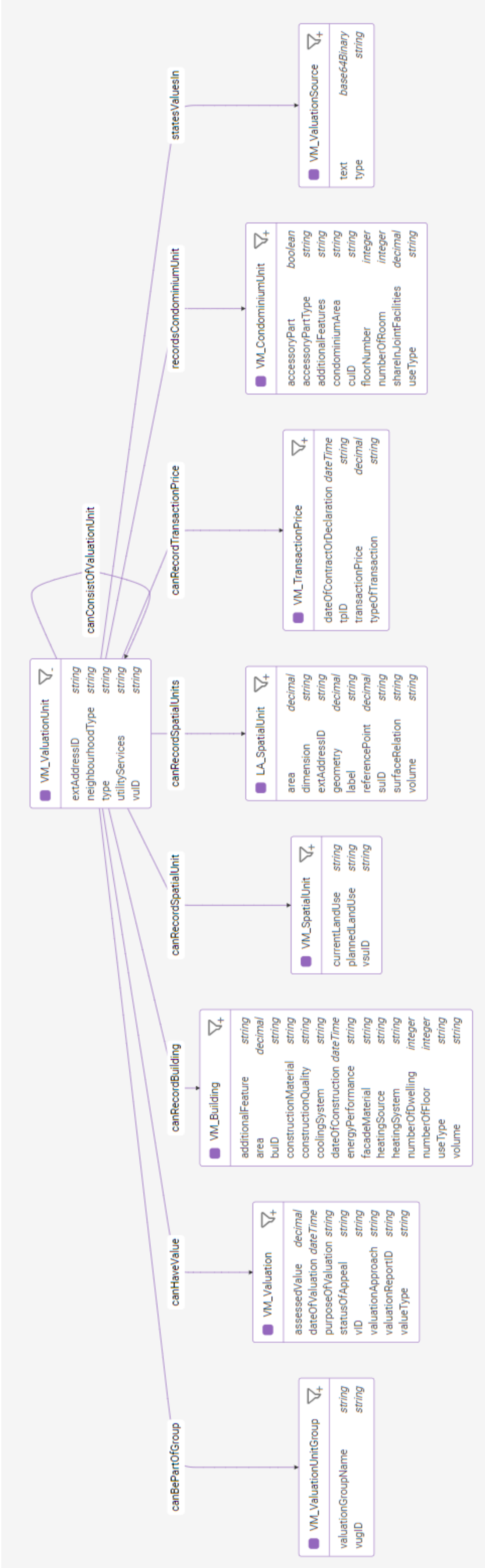

Figure B.43: Class VM_ValuationUnit

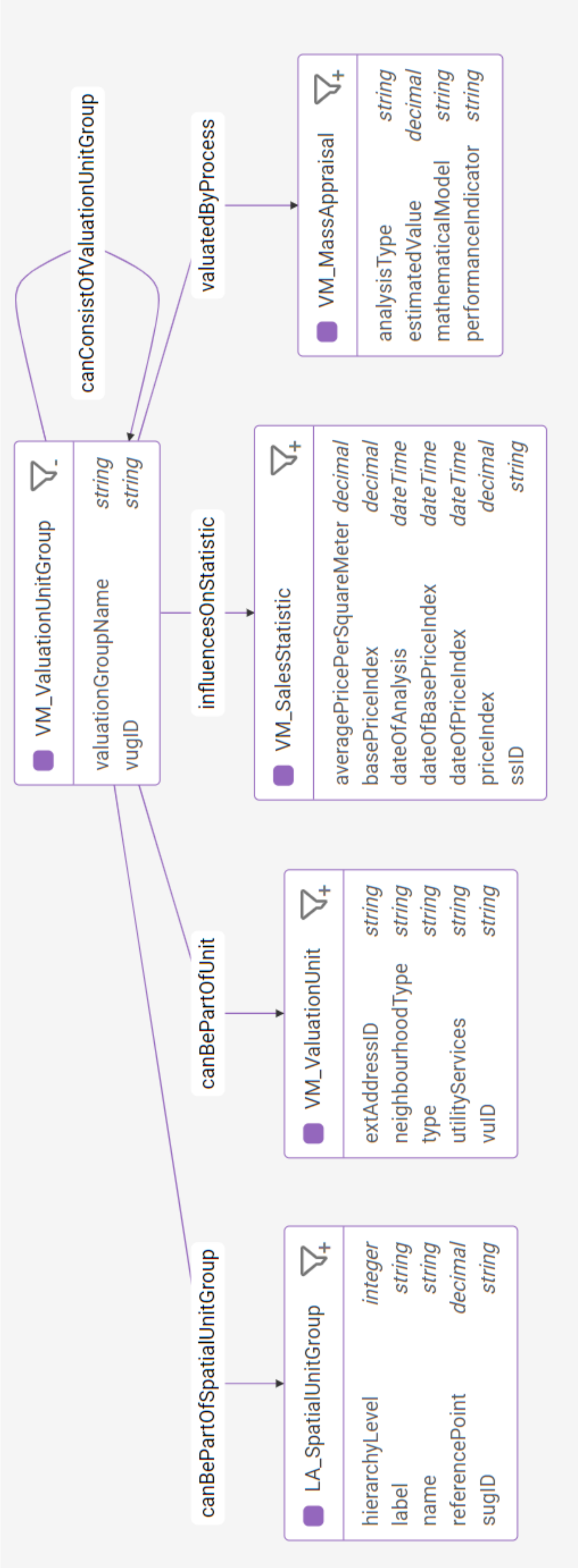

Figure B.44: Class VM_ValuationUnitGroup

C. SPARQL construct queries

The SPARQL construct queries for the development of the datasets conform the ontology are listed down below.

C.1. NL_Address

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX prov: <http://www.w3.org/ns/prov#>
PREFIX nen3610: <http://definities.geostandaarden.nl/def/nen3610#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX bag: <https://bag.basisregistraties.overheid.nl/bag2/def/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX tf: <https://triplydb.com/Triply/function/>
PREFIX triply_optimize: <https://triplydb.com/Triply/sparql/id/value/true>
PREFIX geometry: <https://data.labs.kadaster.nl/ladm/id/geo/>

construct {

  ?adresURI
    a ladm:NL_Address ;
    ladm:addressID ?identificatie ;
    ladm:houseNumber ?huisnummer ;
    ladm:postalCode ?postcode ;
    ladm:streetName ?straatnaam ;
    ladm:NL_addressLetter ?huisletter ;
    ladm:NL_addressNumberAddition ?huisnummertoevoeging ;
    ladm:cityName "Zeewolde"@nl ;
    ladm:country "The Netherlands"@nl ;
    ladm:addressCoordinate ?addressGeo ;
    ladm:NL_province "Flevoland"@nl ;
    ladm:NL_belongsToSpatialUnit ?vboBuildingUnitURI .

  ?addressGeo
    a geo:Geometry ;
    geo:asWKT ?addressGeo0 .

  ?vboBuildingUnitURI
    a ladm:LA_SpatialUnit ;
    a ladm:LA_LegalSpaceBuildingUnit ;
    ladm:NL_suID ?vboId ;
    ladm:NL_belongsToSpatialUnit ?buildingURI ;
    ladm:NL_hasAddress ?adresURI .

  ?buildingURI
  a ladm:LA_SpatialUnit ;
    a ladm:LA_LegalSpaceBuildingUnit ;
    a ladm:NL_WOZ_Building ;
    ladm:NL_surfaceArea ?oppervlakte ;
    ladm:NL_suID ?pandIdentificatie ;
    ladm:NL_geometry ?buildingGeo ;
    ladm:NL_dateOfConstruction ?bouwjaar ;
    ladm:NL_purposeOfUse ?gebruiksdoel .
```

```

  ?buildingGeo
    a geo:Geometry ;
    geo:asWKT ?buildingGeo0 .
}

WHERE {

  {
    ?woonplaatsRegistratie
      a bag:WoonplaatsRegistratie ;
      foaf:primaryTopic ?woonplaats ;
      skos:prefLabel "Zeewolde"@nl .

    ?openbareRuimteRegistratie
      foaf:primaryTopic ?openbareRuimte ;
      bag:ligtIn ?woonplaats ;
      skos:prefLabel ?straatnaam .

    ?nummeraanduidingRegistratie
      bag:ligtAan ?openbareRuimte .
    filter not exists { ?nummeraanduidingRegistratie prov:invalidatedAtTime []
   . }
  }

  ?nummeraanduidingRegistratie
    foaf:primaryTopic ?nummeraanduiding ;
    nen3610:lokaalID ?identificatie ;
    bag:huisnummer ?huisnummer ;
    bag:postcode ?postcode .
  OPTIONAL { ?nummeraanduidingRegistratie bag:huisletter ?huisletter }
  OPTIONAL { ?nummeraanduidingRegistratie bag:huisnummertoevoeging ?
   huisnummertoevoeging }

  ?verblijfsobjectRegistratie
    nen3610:lokaalID ?vboId ;
    bag:hoofdadres ?nummeraanduiding ;
    bag:oppervlakte ?oppervlakte ;
    bag:geometrie ?vboGeo ;
    bag:maaktDeelUitVan ?pand .
  OPTIONAL { ?verblijfsobjectRegistratie bag:gebruiksdoel ?gebruiksdoel }
  filter not exists { ?verblijfsobjectRegistratie prov:invalidatedAtTime []. }

  ?pandRegistratie
    foaf:primaryTopic ?pand ;
    nen3610:lokaalID ?pandIdentificatie ;
    bag:geometrie ?pandGeo ;
    bag:bouwjaar ?bouwjaar .

  bind(tf:project(?vboGeo, <http://www.opengis.net/def/crs/OGC/1.3/CRS84>) as ?
   addressGeo0 )
  bind(uri(concat(str(geometry:),str(?identificatie),"/address-geometry")) as ?
   addressGeo )
  bind(tf:project(?pandGeo, <http://www.opengis.net/def/crs/OGC/1.3/CRS84>) as
   ?buildingGeo0 )
```

```
  bind(uri(concat(str(geometry:),str(?pandIdentificatie),"/building-geometry"))
    as ?buildingGeo )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/address/', str(?
   identificatie))) as ?adresURI )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/building-unit/', str(?
   vboId))) as ?buildingUnitURI )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/building/', str(?
   pandIdentificatie))) as ?buildingURI )

}
```

C.2. LA_LegalSpaceParcel

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX brk: <https://brk.basisregistraties.overheid.nl/brk2/def/>
PREFIX prov: <http://www.w3.org/ns/prov#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX nen3610: <http://definities.geostandaarden.nl/def/nen3610#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX tf: <https://triplydb.com/Triply/function/>
PREFIX triply_optimize: <https://triplydb.com/Triply/sparql/id/value/true>
PREFIX geometry: <https://data.labs.kadaster.nl/ladm/id/geo/>

construct {

  ?parcelURI
    a ladm:LA_SpatialUnit ;
    a ladm:LA_LegalSpaceParcel ;
    ladm:NL_geometry ?pGeo ;
    ladm:NL_suID ?identificatie ;
    ladm:NL_area ?oppervlak.
  ?pGeo
    a geo:Geometry ;
    geo:asWKT ?geometrie .

}

WHERE {

   ?perceelRegistratie
    brk:kadastraleAanduiding/brk:kadastraleGemeente <https://brk.
   basisregistraties.overheid.nl/brk2/id/kadastraleGemeente/1156> ; #25 for
   almere
    brk:begrenzing ?geometrieRd ;
    brk:kadastraleGrootte ?oppervlak ;
    prov:order ?versie ;
    foaf:primaryTopic ?brkPerceel .
    filter not exists { ?perceelRegistratie prov:invalidatedAtTime []. }

  ?brkPerceel
    nen3610:identificatie/nen3610:lokaalID ?identificatie .

  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/parcel/', str(?
   identificatie))) as ?parcelURI )
```

```
  bind(tf:project(?geometrieRd, <http://www.opengis.net/def/crs/OGC/1.3/CRS84>)
     as ?geometrie )
  bind(iri(concat(str(geometry:),?identificatie)) as ?pGeo)

}
```

C.3. NL_PlanUnit

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX nen3610-22: <http://modellen.geostandaarden.nl/def/nen3610-2022#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>
PREFIX imxgeo: <http://modellen.geostandaarden.nl/def/imx-geo#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX geometry: <https://data.labs.kadaster.nl/ladm/id/geo/>

construct {

  ?planunitURI
    a ladm:SP_PlanUnit ;
    ladm:spID ?identificatie ;
    ladm:NL_spatialPlan ?bestemmingsplan ;
    ladm:NL_designatedArea ?bestemming ;
    ladm:NL_geometry ?planGeo .

  ?planGeo
    a geo:Geometry ;
    geo:asWKT ?wkt .
}

WHERE {

  ?bestemming
    a imxgeo:Bestemming ;
    nen3610-22:identificatie ?identificatie ;
    imxgeo:bestemmingsplan ?bestemmingsplan ;
    imxgeo:bestemming ?bestemmingOmschrijving ;
    geo:hasGeometry ?geo .

  ?geo
    geo:asWKT ?wkt .

  bind(uri(concat(str(geometry:),str(?identificatie),"/plan-geometry")) as ?
    planGeo )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/spatial-plan/', str(?
    identificatie))) as ?planunitURI )

}
```

C.4. NL_Party

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
```

```
PREFIX nen3610: <http://modellen.geostandaarden.nl/def/nen3610-2022#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX brp: <https://data.federatief.datastelsel.nl/lock-unlock/brp/def/>
PREFIX brk: <https://data.labs.kadaster.nl/lock-unlock/brk/def/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

construct {

  ?partyURI
    a ladm:LA_Party ;
    ladm:NL_firstName ?voornaam ;
    ladm:NL_lastName ?achternaam ;
    ladm:NL_gender ?geslacht ;
    ladm:NL_bsn ?bsn ;
    ladm:civilStatus ?civilstatus .

  ?rrrURI
    a ladm:LA_RRR ;
    ladm:rID ?zRidentificatie ;
    brk:aandeelNoemer ?noemer ;
    brk:aandeelTeller ?teller ;
    ladm:NL_belongsToAParty ?partyURI ;
    ladm:NL_areAttachedTo ?perceelURI .

  ?perceelURI
    a ladm:LA_SpatialUnit .

}

WHERE {
  {
    ?geregistreerdPersoon
      a brp:GeregistreerdPersoon ;
  nen3610:identificatie ?identificatie ;
  brp:voornaam ?voornaam ;
  brp:achternaam ?achternaam ;
  brp:geslacht ?geslacht ;
  brp:bsn ?bsn ;
  brp:gehuwd ?gehuwd .

    bind(xsd:string(if(bound(?gehuwd), "gehuwd", "alleenstand")) as ?
   civilstatus)
    bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/party/', str(?
   identificatie))) as ?partyURI )
  }

  ?tenaamstelling
    brk:tenNameVan ?geregistreerdPersoon .
  ?tenaamstelling
    brk:van ?zakelijkRecht ;
    brk:aandeelNoemer ?noemer ;
    brk:aandeelTeller ?teller .
  ?zakelijkRecht
    brk:rustOp ?perceel ;
```

```
    nen3610:identificatie ?zRidentificatie .

  bind(strafter(str(?perceel), 'perceel/') as ?perceelId)
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/parcel/', str(?
    perceelId))) as ?perceelURI )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/rrr/', str(?
    zRidentificatie))) as ?rrrURI )

}
```

C.5. NL_WOZ-Value

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX woz: <https://data.labs.kadaster.nl/ladm/woz/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

construct {
  ?wozURI
    a ladm:LA_WOZ-Value ;
    ladm:WOZvalue ?wozwaarde ;
    ladm:dateOfValuation ?datum ;
    ladm:NL_relatesToSpatialUnit ?buildingUnitURI .
}
WHERE {
  ?woz
    woz:assessedValue ?value ;
    woz:dateOfValuation ?datum ;
    woz:relatesToSpatialUnit ?vbo .

  bind(strafter(str(?vbo), 'Verblijfsobject.') as ?buIdentificatie )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/value/', str(?
    buIdentificatie))) as ?wozURI )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/building-unit/', str(?
    buIdentificatie))) as ?buildingUnitURI )

}
```

C.6. NL_PublicLawRestriction

```
PREFIX brk: <https://brk.basisregistraties.overheid.nl/brk/def/>
PREFIX kad: <https://data.kkg.kadaster.nl/kad/model/def/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX nen3610: <http://definities.geostandaarden.nl/def/nen3610#>
PREFIX nen3610-kkg: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX brkpb: <http://www.w3.org/ns/shacl>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>

construct {

```

```
  ?publiclawrestrictionURI
    a ladm:NL_PublicLawRestriction ;
    ladm:publicLawIdentifier ?pdId ;
    ladm:NL_publicLawRestriction ?grondslag ;
    ladm:beginDate ?beginDate ;
    ladm:endDate ?endDate ;
    ladm:NL_leadsToRestriction _:b1 .

  _:b1
    a ladm:NL_SpatialUnitRestriction ;
    ladm:NL_appliesToSpatialUnit ?spURI .

  ?spURI
    a ladm:LA_SpatialUnit ;
    ladm:NL_hasRestriction _:b1 .

}

WHERE {
   ?publiekrechtelijkebeperkingen
     a kad:PubliekrechtelijkeBeperking ;
     kad:gevestigdOp ?gebouwperceel ;
     kad:grondslag/skos:prefLabel ?grondslag ;
     sor:geregistreerdMet ?registratie .

   ?registratie
      sor:primaireBron/sor:documentnummer ?documentnummer ;
      nen3610-kkg:identificatie ?identificatie ;
      nen3610-kkg:beginGeldigheid ?beginDate .
  OPTIONAL { ?registratie nen3610-kkg:eindGeldigheid ?endDate }

  bind(concat(str(?identificatie),'.',str(?documentnummer)) as ?pbId)
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/publiclawrestriction/'
    ,str(?identificatie),'.',str(?documentnummer))) as ?publiclawrestrictionURI)
  bind(strafter(strafter(str(?gebouwperceel), 'id/'), '/') as ?
    gevestigdObjectId )
  bind(if(contains(str(?gebouwperceel), 'perceel'), uri(concat('https://data.
    labs.kadaster.nl/ladm/id/parcel/', str(?gevestigdObjectId))),        if(
    contains(str(?gebouwperceel), 'gebouw'), uri(concat('https://data.labs.
    kadaster.nl/ladm/id/building/', str(?gevestigdObjectId))), '')) as ?spURI)

}
```

C.7. NL_PlanUnit to NL_SpatialUnit

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

construct {

  ?planunitURI geo:sfOverlaps ?buildingURI .
}
WHERE {
  ?pand geo:sfOverlaps ?plan .
```

```
  bind(strafter(str(?plan), 'bestemming/') as ?planId )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/spatial-plan/', str(?
    planId))) as ?planunitURI )

  bind(strafter(str(?pand), 'Pand.') as ?buildingId )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/building/', str(?
    buildingId))) as ?buildingURI )
}
```

C.8. NL_LegalSpaceParcel to NL_SpatialUnit

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX imxgeo: <http://modellen.geostandaarden.nl/def/imx-geo#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>


construct {
  ?parcelURI ladm:NL_isAssociatedWith ?buildingURI .
}

WHERE {
  {
  ?perceel
    a imxgeo:Perceel ;
    imxgeo:ligtInRegistratieveRuimte <https://data.kkg.kadaster.nl/imx-geo/id/
    woonplaats/1075> ;
    imxgeo:bevatBouwwerk ?gebouw .
  }

  ?gebouw
    a imxgeo:Gebouw ;
    imxgeo:hasGeometry ?gGeo.

  OPTIONAL {?gebouw imxgeo:type ?buildingType .}

  bind(strafter(str(?perceel), 'perceel/') as ?perceelId )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/parcel/', str(?
    perceelId))) as ?parcelURI )
  bind(strbefore(strafter(str(?gGeo), '/geo/'), '/bag-geometrie') as ?gebouwId
    )
  bind(uri(concat('https://data.labs.kadaster.nl/ladm/id/building/', str(?
    gebouwId))) as ?buildingURI )

}
```

D. SPARQL queries

The SPARQL queries for the querying of data and the development of the data story are listed down below.

D.1. Real estate transaction: Building information

The following query is developed to query address information, purpose of use, construction year, surface area, woz values and public law restrictions.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>

SELECT ?addressDetails ?purposeofuseLabel ?buildingYear ?buildingarea ?wozValue

WHERE {
  { SELECT * {
      {
        ?adres
          ladm:postalCode ?postcode ;
          ladm:streetName ?streetname ;
          ladm:cityName ?cityName ;
          ladm:houseNumber ?houseNumber .
        OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
        OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
      }

      ?adres ladm:NL_belongsToSpatialUnit ?buildingunit .
      ?buildingunit ladm:NL_belongsToSpatialUnit ?building .

    }
  }

  ?building
    ladm:NL_geometry/geo:asWKT ?buildingGeo ;
    ladm:NL_dateOfConstruction ?buildingYear ;
    ladm:NL_surfaceArea ?buildingarea .
  OPTIONAL { ?building ladm:NL_purposeOfUse ?purposeofuse . }

  OPTIONAL {
    ?buildingunit ^ladm:NL_relatesToSpatialUnit ?woz .
    ?woz
      ladm:assessedValue ?wozValue ;
      ladm:dateOfValuation ?valuationdate .
  }

    bind(strafter(str(?purposeofuse), 'gebruiksdoel/') as ?purposeofuseLabel )
  bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), '
    '),
```

```
      ', ',str(?postcode),', ',str(?cityName)) as ?addressDetails )
}
limit 5
```

D.2. Real estate transaction: Building information on a map

The following query is developed to show building(s) on a map, as geometry.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>

SELECT distinct ?buildingGeo ('red' as ?buildingGeoColor ) ?buildingGeoLabel

WHERE {
  { SELECT * {
      {
        ?adres
          ladm:postalCode ?postcode ;
          ladm:streetName ?streetname ;
          ladm:cityName ?cityName ;
          ladm:houseNumber ?houseNumber .
        OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
        OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
      }

      ?adres ladm:NL_belongsToSpatialUnit ?buildingunit .
      ?buildingunit ladm:NL_belongsToSpatialUnit ?building .

    }
  }

  ?building
    ladm:NL_geometry/geo:asWKT ?buildingGeo ;
    ladm:NL_dateOfConstruction ?buildingYear ;
    ladm:NL_surfaceArea ?buildingarea .
  OPTIONAL { ?building ladm:NL_purposeOfUse ?purposeofuse . }

  OPTIONAL {
    ?buildingunit ^ladm:NL_relatesToSpatialUnit ?woz .
    ?woz
      ladm:assessedValue ?wozValue ;
      ladm:dateOfValuation ?valuationdate .
  }

    bind(strafter(str(?purposeofuse), 'gebruiksdoel/') as ?purposeofuseLabel )
  bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), '
    '),
      ', ',str(?postcode),', ',str(?cityName)) as ?addressDetails )
    bind(strdt(concat(
```

```
    '<h4> Building Information </h4>',
    '<p> Address: ',str(?addressDetails),'</p>',
    '<p> Building year: ',str(?buildingYear),'</p>',
    '<p> Area: ',str(?buildingarea),'</p>',
        if(bound(?purposeofuse), concat('<p> Purpose of Use: ',str(?purposeofuseLabel),'</p>'), ''),
        if(bound(?woz), concat('<p> WOZ Value:',str(?wozValue),'</p>'), ''),
        if(bound(?woz), concat('<p> Valuation Date:',str(?valuationdate),'</p>'), '')),rdf:HTML) as ?buildingGeoLabel)
}
limit 10
```

D.3. Real estate transaction: Parcel information

The following query is developed to query the area of a parcel and the restrictions that are associated with the parcel.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>

SELECT ?addressDetails ?parcelarea ?restriction ?beginDaterestriction

WHERE {
  { SELECT * {
      {
        ?adres
          ladm:postalCode ?postcode ;
          ladm:streetName ?streetname ;
          ladm:cityName ?cityName ;
          ladm:houseNumber ?houseNumber .
        OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
        OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
      }

      ?adres ladm:NL_belongsToSpatialUnit ?buildingunit .
      ?buildingunit ladm:NL_belongsToSpatialUnit ?building .

    }
  }

  OPTIONAL { ?parcel
      ladm:NL_isAssociatedWith ?building ;
      ladm:NL_area ?parcelarea ;
      ladm:NL_geometry/geo:asWKT ?parcelGeo }

  OPTIONAL {
    ?spatialunitrestriction ladm:NL_appliesToSpatialUnit ?parcel.
    ?publiclawrestriction
      a ladm:NL_PublicLawRestriction ;
      ladm:NL_leadsToRestriction ?spatialunitrestriction ;
      ladm:NL_publicLawRestriction ?restriction ;
```

```
      ladm:beginDate ?beginDaterestriction . }

  bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), '
    '),
      ', ',str(?postcode),', ',str(?cityName)) as ?addressDetails )
    bind(strdt(concat(
        '<h4> Parcel Information </h4>',
        '<p> Address: ',str(?addressDetails),'</p>',
        '<p> Area: ',str(?parcelarea),'</p>'),rdf:HTML) as ?parcelGeoLabel)
}
limit 5
```

D.4. Real estate transaction: Parcel information on a map

The following query is developed to show the parcels on a map.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>

SELECT ?parcelGeo ?parcelGeoLabel

WHERE {
  { SELECT * {
      {
        ?adres
          ladm:postalCode ?postcode ;
          ladm:streetName ?streetname ;
          ladm:houseNumber ?houseNumber .
        OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
        OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
      }

      ?adres ladm:NL_belongsToSpatialUnit ?buildingunit .
      ?buildingunit ladm:NL_belongsToSpatialUnit ?building .

    }
  }

  OPTIONAL { ?parcel
      ladm:NL_isAssociatedWith ?building ;
      ladm:NL_area ?parcelarea ;
      ladm:NL_geometry/geo:asWKT ?parcelGeo }

  OPTIONAL {
    ?spatialunitrestriction ladm:NL_appliesToSpatialUnit ?parcel.
    ?publiclawrestriction
      a ladm:NL_PublicLawRestriction ;
      ladm:NL_leadsToRestriction ?spatialunitrestriction ;
      ladm:NL_publicLawRestriction ?restriction ;
```

```
      ladm:beginDate ?beginDaterestriction . }

    bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), '
    '),
      ', ',str(?postcode)) as ?addressDetails )
    bind(strdt(concat(
        '<h4> Parcel Information </h4>',
        '<p> Address: ',str(?addressDetails),'</p>',
        '<p> Area: ',str(?parcelarea),'m^2</p>',
        if(bound(?restriction), concat('<p> Spatial Restriction: ',str(?
    restriction),'</p>'), '')),rdf:HTML) as ?parcelGeoLabel)
}
limit 10
```

D.5. Real estate transaction: Completeness of personal information

The following query is developed to query personal information.

```
PREFIX graph: <https://data.labs.kadaster.nl/ladm/ladm-test/graphs/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT distinct ?bsn ?firstname ?lastname ?civilstatus
WHERE {
  ?party
    a ladm:LA_Party ;
    ladm:NL_bsn ?bsn ;
    ladm:NL_firstName ?firstname ;
    ladm:NL_lastName ?lastname ;
    ladm:NL_gender ?gender ;
    ladm:civilStatus ?civilstatus .
}
  limit 5
```

D.6. Real estate transaction: Current ownership of real estate

The following query is developed to query current ownership of real estate information.

```
PREFIX graph: <https://data.labs.kadaster.nl/ladm/ladm-test/graphs/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT distinct ?addressDetails ?bsn ?firstname ?lastname ?civilstatus
WHERE {
  {
    ?adres
```

```
      ladm:NL_belongsToSpatialUnit ?buildingunit ;
      ladm:postalCode ?postcode ;
      ladm:streetName ?streetname ;
      ladm:cityName ?cityName ;
      ladm:houseNumber ?houseNumber .
    OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
    OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
  }

  ?buildingunit ladm:NL_belongsToSpatialUnit ?building .
  ?parcel ladm:NL_isAssociatedWith ?building .

  ?rrr
    ladm:NL_belongsToAParty ?party ;
    ladm:NL_areAttachedTo ?parcel .

  ?party
    a ladm:LA_Party ;
    ladm:NL_bsn ?bsn ;
    ladm:NL_firstName ?firstname ;
    ladm:NL_lastName ?lastname ;
    ladm:NL_gender ?gender ;
    ladm:civilStatus ?civilstatus .

  bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), '
    '),
      ', ',str(?postcode),', ',str(?cityName)) as ?addressDetails )

}
  limit 5
```

D.7. Building permit: Spatial plan information

The following query is developed to query address information and spatial plan information.

```
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT ?addressDetails ?document
WHERE
{
  { SELECT * {
      {
        ?adres
          ladm:postalCode ?postcode ;
          ladm:houseNumber ?housenumber ;
      ladm:streetName ?streetname ;
      ladm:cityName ?cityName .
```

```
        OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
        OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
      }

      ?adres ladm:NL_belongsToSpatialUnit ?buildingunit .
      ?buildingunit ladm:NL_belongsToSpatialUnit ?building .
    }
  }

  ?spatialplan
    a ladm:SP_PlanUnit ;
    geo:sfOverlaps ?building ;
  ladm:NL_designatedArea ?bestemming ;
  ladm:NL_spatialPlan ?spatialplandocument ;
  ladm:spID ?spId .

  bind(concat(str(?streetname),' ',str(?housenumber),
      if(bound(?houseletter),concat(str(?houseletter)),''),
      if(bound(?housenumberaddition),concat('-',str(?housenumberaddition)),''),
    ', ',str(?postcode),', ',str(?cityName)) as ?addressDetails)

  bind(uri(str(?spatialplandocument)) as ?document )
}
limit 5
```

D.8. Building permit: Spatial plan information on a map

The following query is developed to query spatial plan information on a map based on geometry.

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT ?wkt ('red'as ?wktColor)
     ?wktLabel
WHERE
{
  { SELECT * {
      {
        ?adres
          ladm:postalCode ?postcode ;
          ladm:houseNumber ?housenumber .
        OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
        OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
      }

      ?adres ladm:NL_belongsToSpatialUnit ?buildingunit .
      ?buildingunit ladm:NL_belongsToSpatialUnit ?building .
    }
  }

  ?spatialplan
```

```
    a ladm:SP_PlanUnit ;
    geo:sfOverlaps ?building ;
  ladm:NL_designatedArea ?bestemming ;
  ladm:NL_spatialPlan ?spatialplandocument ;
  ladm:spID ?spId ;
  ladm:NL_geometry/geo:asWKT ?wkt .

  bind(strdt(concat(
    '<h4> Spatial Plan Exists </h4>',
    '<p>Link: <a href="',str(?spatialplandocument),'" target="_blank">',str(?
   spId),'</a></p>'),rdf:HTML) as ?wktLabel)
}
limit 10
```

D.9. Building permit: Personal information

The following query is developed to query personal information.

```
PREFIX graph: <https://data.labs.kadaster.nl/ladm/ladm-test/graphs/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT distinct ?bsn ?firstname ?lastname ?gender
WHERE {
  ?party
    a ladm:LA_Party ;
    ladm:NL_bsn ?bsn ;
    ladm:NL_firstName ?firstname ;
    ladm:NL_lastName ?lastname ;
    ladm:NL_gender ?gender .
}
limit 1
```

D.10. Building permit: Ownership information

The following query is developed to query current ownership of real estate information.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT ?addressDetails ?bsn ?firstName ?lastName {
  {
    {
      ?party
        ladm:NL_bsn ?bsn ;
        ladm:NL_firstName ?firstName ;
        ladm:NL_lastName ?lastName . }

    ?address
      ladm:houseNumber ?houseNumber ;
      ladm:streetName ?streetname ;
```

```
      ladm:cityName ?cityName ;
      ladm:postalCode ?postcode .
    OPTIONAL { ?address ladm:NL_addressLetter ?houseletter }
    OPTIONAL { ?address ladm:NL_addressNumberAddition ?housenumberaddition }
  }

  ?verblijfsobject
    ladm:NL_hasAddress ?address ;
    ladm:NL_belongsToSpatialUnit ?building .

  ?building
    a ladm:LA_LegalSpaceBuildingUnit .
  ?parcel ladm:NL_isAssociatedWith ?building .
  ?rrr
    ladm:NL_areAttachedTo ?parcel ;
    ladm:NL_belongsToAParty ?party .

  bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), '
    '),
      ', ',str(?postcode)) as ?addressDetails )
}
limit 5
```

D.11. Building permit: Cadastral information

The following query is developed to query cadastral information of the real estate and parcel the real estate is located on.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT ?buildingGeo ('red' as ?buildingGeoColor ) ?buildingGeoLabel ?parcelGeo
    ?parcelGeoLabel
WHERE
{
  {
    ?address
      ladm:houseNumber ?houseNumber ;
      ladm:streetName ?streetname ;
      ladm:postalCode ?postcode .
    OPTIONAL { ?address ladm:NL_addressLetter ?houseletter }
    OPTIONAL { ?address ladm:NL_addressNumberAddition ?housenumberaddition }
  }
  ?address ladm:NL_belongsToSpatialUnit ?buildingUnit.
  ?buildingUnit ladm:NL_belongsToSpatialUnit ?building.
  ?building
    ladm:NL_geometry/geo:asWKT ?buildingGeo ;
    ladm:NL_dateOfConstruction ?buildingYear ;
    ladm:NL_surfaceArea ?buildingarea .
```

```
  OPTIONAL { ?building ladm:NL_purposeOfUse ?purposeofuse . }
  OPTIONAL { ?parcel
      ladm:NL_isAssociatedWith ?building ;
      ladm:NL_area ?parcelarea ;
      ladm:NL_geometry/geo:asWKT ?parcelGeo }

  bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), ''),
      ', ',str(?postcode)) as ?addressDetails )
  bind(strafter(str(?purposeofuse), 'gebruiksdoel/') as ?purposeofuseLabel )
  bind(strdt(concat(
    '<h4> Building Information </h4>',
    '<p> Address: ',str(?addressDetails),'</p>',
    '<p> Building year: ',str(?buildingYear),'</p>',
    '<p> Area: ',str(?buildingarea),'</p>',
        if(bound(?purposeofuse), concat('<p> Purpose of Use:',str(?purposeofuseLabel),'</p>'), '')),rdf:HTML) as ?buildingGeoLabel)
  bind(strdt(concat(
        '<h4> Parcel Information </h4>',
        '<p> Address: ',str(?addressDetails),'</p>',
        '<p> Area: ',str(?parcelarea),'</p>'),rdf:HTML) as ?parcelGeoLabel)
}
limit 5
```

D.12. Building permit: Public law restriction information

The following query is developed to query address information and public law restriction information related to the address.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX sor: <https://data.kkg.kadaster.nl/sor/model/def/>
PREFIX nen3610: <https://data.kkg.kadaster.nl/nen3610/model/def/>
PREFIX ladm: <https://data.labs.kadaster.nl/2024/ladm#>

SELECT ?addressDetails ?restriction ?beginDaterestriction

WHERE
{
  { SELECT * {
      {
        ?adres
          ladm:postalCode ?postcode ;
          ladm:streetName ?streetname ;
          ladm:cityName ?cityName ;
          ladm:houseNumber ?houseNumber .
        OPTIONAL { ?adres ladm:NL_addressLetter ?houseletter }
        OPTIONAL { ?adres ladm:NL_addressNumberAddition ?housenumberaddition }
      }

      ?adres ladm:NL_belongsToSpatialUnit ?buildingunit .
      ?buildingunit ladm:NL_belongsToSpatialUnit ?building .
      ?parcel ladm:NL_isAssociatedWith ?building .
```

```
    }
  }

  ?spatialunitrestriction ladm:NL_appliesToSpatialUnit ?parcel.
  ?publiclawrestriction
    a ladm:NL_PublicLawRestriction ;
                          ladm:NL_leadsToRestriction ?spatialunitrestriction ;
                          ladm:NL_publicLawRestriction ?restriction ;
                          ladm:beginDate ?beginDaterestriction .

  bind(concat(str(?streetname),' ',str(?houseNumber),
      if(bound(?houseletter), str(?houseletter), ''),
      if(bound(?housenumberaddition), concat('-', str(?housenumberaddition)), '
    '),
      ', ',str(?postcode),', ',str(?cityName)) as ?addressDetails )
}
  limit 5
```

E. Data story building permit for usability test

The data story for building permit application was translated to the Dutch language for the usability test. The link to the data story cannot be shared publicly due to the inclusion of closed data. Therefore, the translated data story is attached as a print. Note that this printout of the data story for the application of a building permit does not show that a user can enter a variable, as is the case in the working data story.

Aanvraag bouwvergunning

By MarjoleinvanAalst

DISCLAIMER: De gegevens die worden gebruikt om een bouwaanvraag aan te tonen zijn volledig nep. Er is geen persoonlijk identificeerbare informatie beschikbaar in deze datasets.

Achtergrond van het project

Landbeheer vereist toegang tot gegevens uit verschillende bronnen om te voldoen aan verschillende gebruikssituaties. Om het opvragen van informatie voor deze gebruikssituaties te ondersteunen, is voorgesteld een portaal te ontwikkelen om informatie over landbeheer te integreren. De integratie van deze informatie is gebaseerd op de implementatie van het Land Administration Domain Model (ISO19152) als een ontologie. De ontwikkeling van de ontologie is gedaan als onderdeel van een studentenproject met de TU Delft en wordt voortgezet als een onderzoeks- en ontwikkelingsproject.

Een van de use cases voor de ontwikkeling van een op standaarden gebaseerd portaal voor geïntegreerde informatie uit de landadministratie is de aanvraag van een bouwvergunning. In Nederland zijn er verschillende stappen in dit proces en is het nodig om informatie op te halen uit meerdere, gedistribueerde bronnen, zowel open databronnen als gesloten of betaalde databronnen. Dit is in Nederland goed geregeld en de relevante partijen zijn al in staat om toegang te krijgen tot en gebruik te maken van de informatie in deze bronnen. Een geïntegreerde gegevensbron verbetert de efficiëntie waarmee informatie kan worden opgevraagd door gebruikers. In de onderstaande demonstrator zijn namelijk nog maar twee informatiepunten nodig van de gebruiker, het adres en het bsn dat hoort bij een bepaalde bouwaanvraag. Met deze informatie kunnen ruimtelijke plannen, wettelijke beperkingen, persoonlijke gegevens en kadastrale informatie worden opgehaald op basis van een aantal eenvoudig te definiëren SPARQL-queries. Voorheen was hiervoor toegang tot verschillende gegevensbronnen nodig, elk met een complex model en verschillende opvraagmechanismen.

Dit verhaal demonstreert het ophalen van gegevens in verschillende stadia van de processtroom. Dit gebeurt door het bevragen van de informatie die nu geïntegreerd is met behulp van de LADM-ontologie op basis van een set vragen die relevant zijn voor gebruikers van het portaal in verschillende stadia van de processtroom.

Demonstrator Opmerkingen:

- De gegevens die beschikbaar zijn in deze demonstrator hebben alleen het ruimtelijke bereik van Almere en Zeewolde.

Voorbereiding van aanvraag bouwvergunning

Informatie ruimtelijk plannen

- Welk(e) ruimtelijk(e) plan(nen) zijn verbonden aan het specifieke adres dat bij een bouwplan hoort?

De onderstaande zoekopdrachten gebruiken het portaal om deze vraag te beantwoorden. In de eerste zoekopdracht worden de resultaten teruggegeven als een tabel en in de tweede zoekopdracht worden deze resultaten op een kaart geplaatst. Met de invoerparameters kan de gebruiker van dit portaal eenvoudigweg de adresgegevens invullen die bij een bouwplan horen en, wanneer deze worden uitgevoerd, een (lijst van) ruimtelijk(e) plan(nen) ophalen die bij dit adres horen.

Technische opmerking: Door op de knop 'probeer deze query zelf' te klikken, is het mogelijk om de onderliggende query te zien die is gedefinieerd om het beantwoorden van deze vraag te ondersteunen. Dit is een SPARQL query; de eigen querytaal die wordt gebruikt om informatie op te halen uit gekoppelde gegevensbronnen. De queryparameters die voor deze SPARQL query zijn gedefinieerd, de adresgegevens, maken het voor de gebruiker van het landbeheerportaal mogelijk om eenvoudig adresgegevens in te voeren en deze informatie in een tabel terug te geven zonder kennis van SPARQL te hebben.

Als de volgende zoekopdracht geen resultaten oplevert, zijn er geen ruimtelijk ;plan van toepassing op een bepaald adres.

Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 8, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 12, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Kemphaanweg 1, 1358AA, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-

De volgende zoekopdracht visualiseert dezelfde resultaten als de bovenstaande zoekopdracht, maar dan op een kaartinterface. Door op de getoonde geometrie te klikken, is het mogelijk om het specifieke ruimtelijke plandocument te zien dat bij deze geometrie hoort.

Na het identificeren van een ruimtelijk plan en het ophalen van deze informatie, moet de aanvrager van de bouwvergunning de informatie in het ruimtelijk plan beoordelen om de volgende vraag te beantwoorden:

- Is het bouwplan in overeenstemming met het/de ruimtelijke plan(nen)?

Dit kan niet worden gedaan op basis van een eenvoudige SPARQL-query, omdat hiervoor specialistische kennis nodig is en dit hier niet wordt gedemonstreerd. De informatie die nodig is om deze beoordeling uit te voeren, is echter opgenomen in de resultaten van de vorige zoekopdrachten. Als de plannen moeten worden aangepast, wordt dit gedaan door de aanvrager en vervolgens wordt het bouwplan ingediend bij de gemeente. Hiermee is de voorbereidende fase van deze processtroom afgerond.

Daadwerkelijke aanmelding bouwvergunning

Na het indienen van de bouwvergunning in de vorige fase volgt een opeenvolgende fase.

Persoonlijke informatie

De eerste stap waarbij informatie uit het portaal moet worden gehaald, is het controleren op persoonlijke informatie. Om de relevante informatie voor deze stap op te halen, wordt de volgende vraag gesteld:

- Komt de persoonlijke informatie op de aanvraag overeen met de informatie in de basisregistratie personen?

Om deze vraag te beantwoorden, moet een gemeenteambtenaar het bsn invoeren dat in de bouwaanvraag is gedefinieerd en de persoonsgegevens ophalen die bij dit bsn-nummer horen. De volgende zoekopdracht geeft persoonlijke informatie. Met de invoerparameter kan de gebruiker persoonlijke informatie opvragen voor een gedefinieerd bsn-nummer.

35.185.787	Ilse	Berkelmans	V

De resultaten van deze zoekopdracht moeten vervolgens worden gecontroleerd aan de hand van de persoonlijke informatie die bij een bepaald adres hoort, zoals geregistreerd in het Kadaster Basisregistratie. Hiervoor moeten de personen die eigenaar zijn van een bepaald gebouw of perceel worden bevraagd. Hiervoor moet de volgende vraag als zoekopdracht worden gedefinieerd:

- Welke persoon is geregistreerd als eigenaar van een bepaald gebouw, appartement en/of perceel?

Het portaal kan deze vraag op twee manieren beantwoorden. De eerste manier is door een adres in te voeren zoals genoteerd in de bouwaanvraag en te controleren op een match in

BSN of door het BSN-nummer in te voeren dat bij het bouwplan hoort en te controleren of het adres overeenkomt met het adres dat op het bouwplan staat. Beide opties worden geïmplementeerd in de onderstaande zoekopdrachten.

Pluvierenweg 9-257, 3898LL	3.323.109	Evert	Schults
Pluvierenweg 9-582, 3898LL	12.789.580	Merle	Goedegebuure
Slingerweg 1-655, 3896LD	87.430.153	Hilde	van Ginneken
Slingerweg 1-656, 3896LD	87.430.153	Hilde	van Ginneken
Pluvierenweg 9-556, 3898LL	93.258.788	Emma	Carlier

Gebouwinformatie

Nadat de persoonlijke informatie is geverifieerd, moet de ruimtelijke informatie en informatie over publiekrechtelijke beperkingen worden gecontroleerd. Om dit te controleren worden de volgende vragen gesteld:

- Welke kadastrale informatie is beschikbaar voor het adres waarop het bouwplan betrekking heeft?
- Welke ruimtelijke plannen zijn van toepassing op het adres van het voorgestelde bouwplan?
- Op welk ruimtelijk gebied is een ruimtelijk plan verbonden aan een specifiek adres van toepassing?
- Welke publiekrechtelijke beperkingen zijn van toepassing op het adres van het voorgestelde bouwplan?

De eerste zoekopdracht zoekt eenvoudigweg naar alle kadastrale gegevens die bij een bepaald adres horen, inclusief de ouderdom en locatie van het gebouw, het perceel waarop het gebouw staat en de grootte van elk van deze percelen. De tweede query is een herhaling van de zoekopdracht die de aanvrager in de voorbereidende fase heeft gebruikt. Hier wordt de adresinformatie die bij een bouwplan hoort gebruikt als invoerparameter om de ruimtelijke plannen te identificeren en vervolgens op een kaart te plaatsen. De laatste zoekopdracht wordt ook gedefinieerd op basis van de beschikbare adresinformatie en alle beschikbare wettelijke beperkingen worden weergegeven.

Kadastrale informatie

Ruimtelijke plannen

Als de volgende zoekopdracht geen resultaten oplevert, zijn er geen ruimtelijke plannen van toepassing op een bepaald adres.

Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 8, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 12, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Kemphaanweg 1, 1358AA, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-
Weteringweg 2, 1358AK, Almere	http://ruimtelijkeplannen.nl/documents/NL.IMRO.00340000BP1H5BP01-

De volgende zoekopdracht visualiseert dezelfde resultaten als de bovenstaande zoekopdracht, maar dan op een kaartinterface. Door op de getoonde geometrie te klikken, is het mogelijk om het specifieke ruimtelijke plandocument te zien dat bij deze geometrie hoort.

Publiekrechtelijke beperkingen

Als de volgende zoekopdracht geen resultaten oplevert, zijn er geen publiekrechtelijke beperkingen van toepassing op een bepaald adres.

Zandzuigerstraat 61, 1333MX, Almere	Opiumwet: Sluiting object	2020-08-20
Zandzuigerstraat 61, 1333MX, Almere	Opiumwet: Sluiting object	2020-11-23
Zandzuigerstraat 63, 1333MX, Almere	Opiumwet: Sluiting object	2020-08-20
Zandzuigerstraat 63, 1333MX, Almere	Opiumwet: Sluiting object	2020-11-23
Zandzuigerstraat 65, 1333MX, Almere	Opiumwet: Sluiting object	2020-08-20

Source datasets:

- I Integrated Portal for Land Administration

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