A standards-based portal for integrated Land Administration information A case study of the Netherlands

Marjolein VAN AALST, Peter VAN OOSTEROM, Lexi ROWLAND, Erwin FOLMER, and Hendrik PLOEGER, The Netherlands

Key words: Land Administration, the Netherlands, LADM Edition II, country profile, linked data portal

SUMMARY

Land administration involves the systematic management of information about land. In the Netherlands, such information is dispersed across various geoportals for land registry, public law restriction, valuation and spatial plan information, each with distinct approaches to data delivery and processing. The question is, if this collection of separated portals can be harmonized and replaced by an integrated land administration system. The Land Administration Domain Model (LADM) Edition II offers a conceptual framework to unify land administration information and in case multiple authorities are involved, the Spatial Data Infrastructure (SDI) can be used to link and shared the information in an harmonized manner. This research explores the benefits and drawbacks of implementing LADM Edition II for data dissemination in the Netherlands using a linked data portal. Two quite representative use cases were modelled (1. Preparing for real estate transaction and 2. Preparing when applying for a building permit) and both needed information from multiple portals to complete the tasks. Given the current situation of non-harmonized terminology, separate portals with different user interfaces, the users would benefit from a more harmonized and integrated portal. For conceptual harmonization the country-specific Netherlands LADM profile was developed and documented the Unified Modelling Language (UML) class diagrams. This is the first published LADM country profile covering multiple parts. In order to provide a uniform access, the UML conceptual model was converted into an Web Ontology Language (OWL) ontology model and populated with data from the Dutch registers in accordance with the ontology. The developed SPARQL queries enabled the construction of a data story collecting and presenting information through a single portal for our use cases. The findings show that implementing LADM with linked data can enhance efficiency and usability by integrating multiple registers into a single geoportal. However, achieving this requires significant initial investment, including validating the country profile, aligning Dutch registers with LADM, and developing SPARQL queries.

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1. INTRODUCTION

Countries with disaggregated LASs fail to take advantage of the opportunities that may exist in their separate LASs to address national needs. 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. The United Nations Integrated Geospatial Information Framework (UN-GGIM, 2020) 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. This study will assess and evaluate the implementation of LADM in the Netherlands utilizing use cases and offer recommendations for future developmental work.

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. These geoportals include (with their Dutch names): 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 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.

The remainder of this paper is organized as follows. Section 2 gives a short introduction to the ISO standard for land administration and also describes the Dutch land administration landscape. The research question, and related use cases driving our research are presented in Section 3. The developed multi-part Netherlands LADM country profile and its linked data implementation are covered in respectively Sections 4 and 5. The assessment and discussion are provided in Section 6. Finally, Section 7 summarizes the main results and indicates some future work.

2. LAND ADMINISTRATION DOMAIN MODEL

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 (after UN-ECE, 1996). 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). 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, 2024). Because of these characteristics LADM can facilitate the exchange of data to and from different land registers or geoportals (Lemmen, 2012; 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. The four parts of LADM Edition II included in this research are the following (ISO, 2024):

- Part 1 – Generic Conceptual Model, providing a general overview of the model and serving as an overarching standard that supports Parts 2 to 5.
- Part 2 – Land Registration, entails detailed descriptions about the classes introduced in Part 1.
- Part 4 – Valuation Information, specifies the semantics and characteristics of valuation information.
- Part 5 – Spatial Plan Information, defines a general schema for spatial plan information.

Land registration in the Netherlands is managed by Kadaster (the Dutch Cadastre, Land Registry and Mapping Agency), an official independent administrative body. The Cadastral Act outlines the tasks of the Kadaster, which include maintaining the public registers of registered property (i.e. the registration of deeds concerning transactions in land, plus registered ships and aircraft), and maintaining and updating the cadastral information in the base land register, and

the cadastres for registered 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).

Spatial planning and public law restrictions are at various levels of the government, from state to municipalities. The valuation is at municipality level, but guided by national guidelines.
The Netherlands government operates a system of key registers. that have an important role in organizing and managing essential information in the various domains. Each key register contains high-quality data (so-called “authentic data”), which is to be used by all government institutions in the performance of public-law tasks. Although the key registers are interconnected (see Figure 1) with the aims to facilitate the exchange of data between the registers and to guarantee the accuracy of the authentic data, the data in these geoportals are each structured and formatted according to the key registers they include. This which leads to cross-sector interoperability problems when trying to link these different LAS (Çağdaş and Stubkjær, 2014). There is also no central access to the key registers. As a result land administration information in the Netherlands must be accessed through various geoportals.

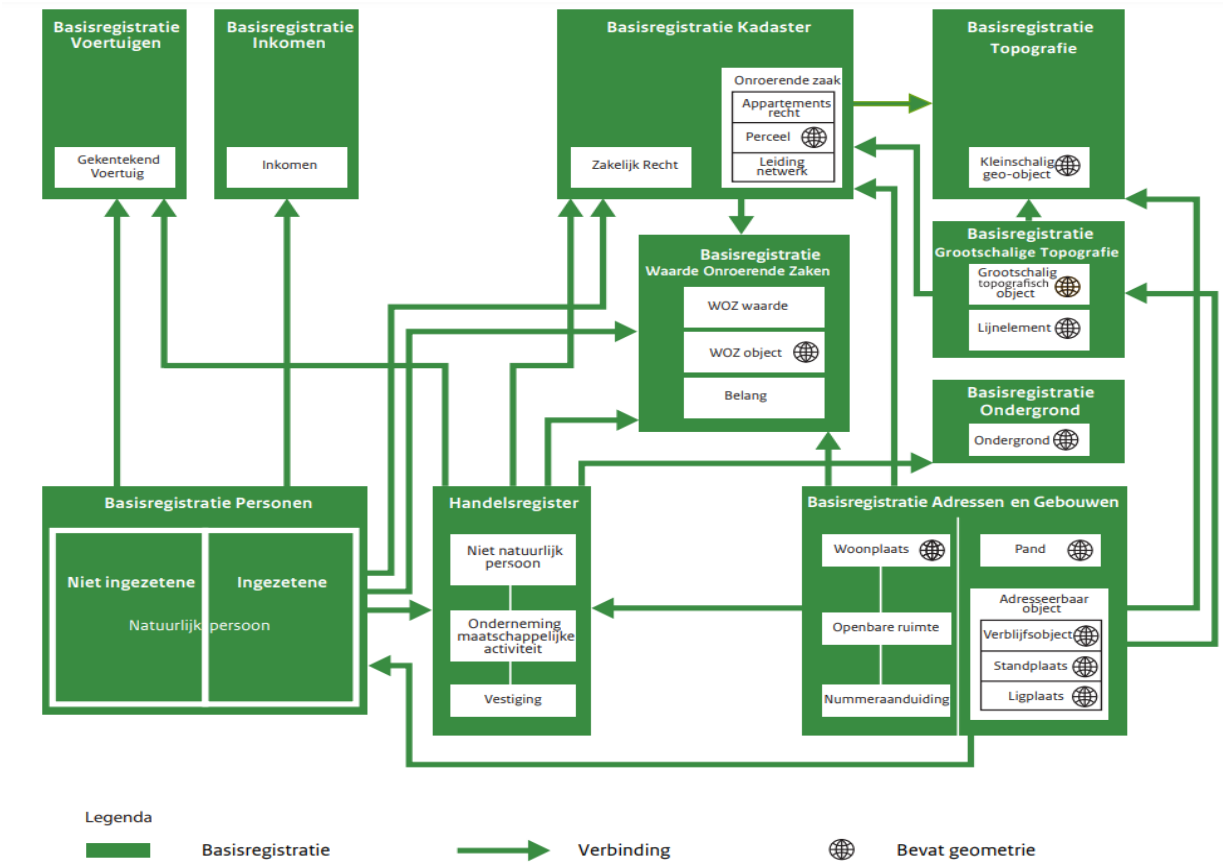

Figure 1. System sheet of key registers in the Netherlands (Overheid, 2020)

3. RESEARCH QUESTION AND USE CASES

This paper investigates if the Land Administration Domain Model (LADM) Edition II offers a conceptual framework to unify land administration information within a Spatial Data Infrastructure (SDI), covering land registration, marine georegulation, valuation, and spatial planning. This research explores the benefits and drawbacks of implementing LADM Edition II for data dissemination in the Netherlands using a linked data portal.
Two use cases are identified to assess the effects of the application and implementation of LADM in the Netherlands. 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).

3.1 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. Currently, there are at least 9 registers that need to be consulted in the preparation for real estate transaction. Namely, the key register of addresses and buildings (BAG), the base land register (BRK), public law restrictions (BRK-PB), the Wozwaardeloket geoportal, the bankruptcy register, the guardianship and administration register, the identity verification register (VIS), the key register of natural persons (BRP) or the key register of legal persons also known as the commercial register (HR). As the Dutch legal system of land administration and land transactions must be characterized as a registration of deeds, the legal certainty in a land transaction cannot be based on information from the key registers. Next to these registers also the public registers for registered property must be inspected (Zevenbergen, 2002; Bartels et al., 2021). These registers contain the deeds concerning the transactions in land, and therefore provide the source documents for the information in the base land register.

3.2 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 the conceptually harmonized data from multiple registers so a comprehensive file of limitations will be known. Currently, there are at least 3 registers that need to be consulted in the preparation when applying for a building permit. Namely, the key register of persons (BRP) or commercial register (HR), public law restrictions (BRK-PB) and Omgevingsloket for spatial plans.

4. COUNTRY PROFILE OF THE NETHERLANDS

The implementation of LADM in a country involves developing a country profile (e.g. UML application schema) (Kara et al., 2021). 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 research, comprising: the BAG, the BRK, public law restrictions, the WOZ (valuation) and spatial plans. Three country profiles are developed and country specific classes are added indicated by the prefix 'NL'. These country profiles will be linked together to form one model during implementation.

4.1 Country profile for the land registry

A required relationship is added to LA_RRR as a result of developments from the first version of the LADM model. Following the Kadaster Act the class LA_BAUnit has been merged with LA_SpatialUnit as there are no basic administrative units registered in the Netherlands. The NL_Address class is introduced as an external class from the annex External Classes of Part 2 - Land registration (ISO, 2025) to cover country-specific information in land registration. 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 class NL_SpatialUnitRestriction has been added to the country profile to indicate the result of a public law restriction placed on a spatial unit. Finally, the class NL_RegulatoryArea has been added, which indicates the area of application of the public law restriction; see Figure 2.

4.2 Country profile for valuation information

Additional NL classes are taken from previous research on the country profile of the Netherlands for valuation information (Kara et al., 2019). To represent the object characteristics used in property valuation, new classes were created, including: NL_WOZ_Building, NL_WOZ_OccupancyUnit, NL_WOZ_Parcel, and NL_WOZ_Subject. The NL_WOZ-object class is specified as a child class of VM_ValuationUnit. 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; see Figure 3.

4.3 Country profile for spatial plan information

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 Figure 4.

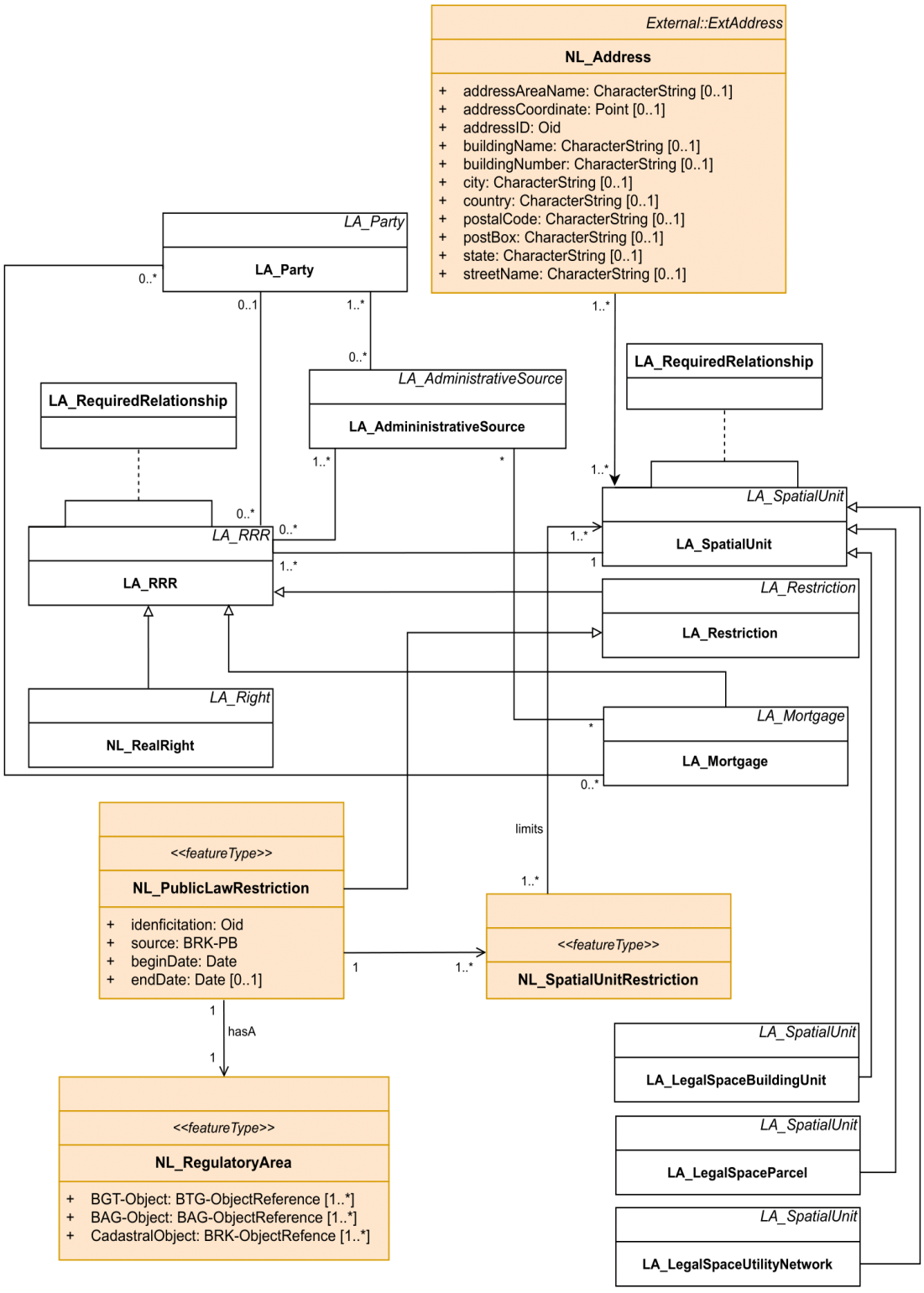

Figure 2. LADM Country profile of the Netherlands for land registry

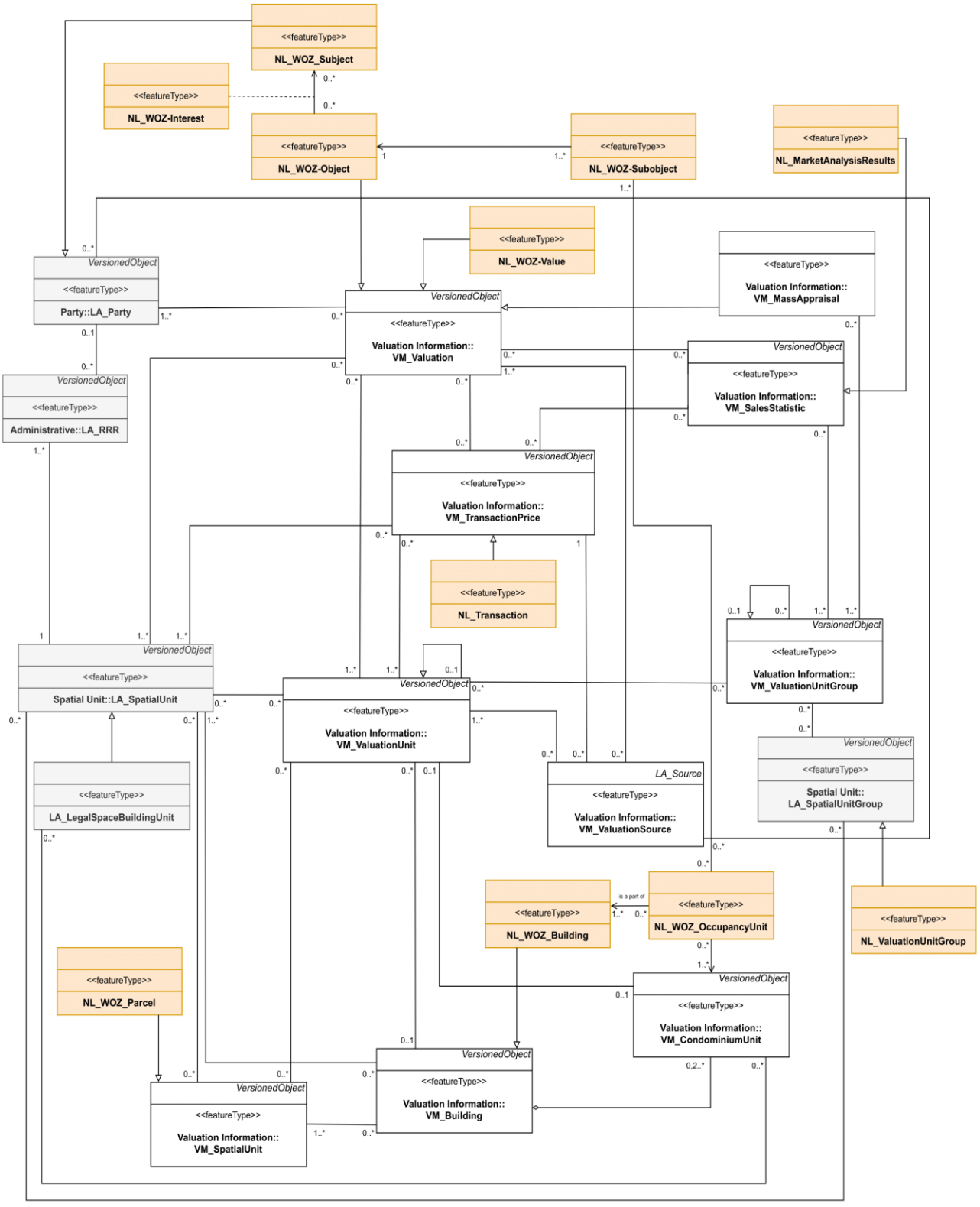

Figure 3. Country profile of the Netherlands for valuation information

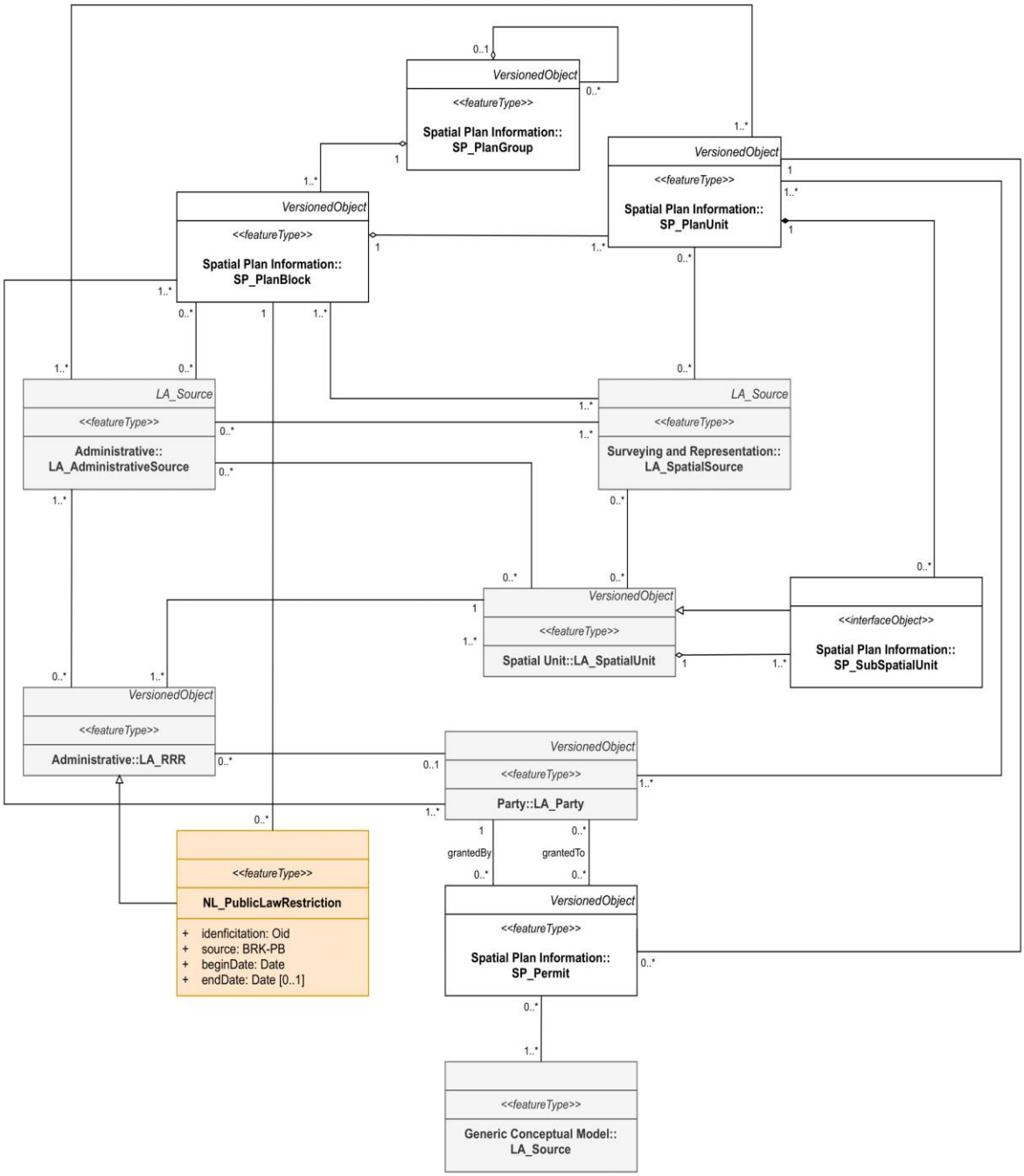

Figure 4. Country profile of the Netherlands for spatial plan information

5. IMPLEMENTATION WITH LINKED DATA

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 through querying of the use cases. 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). Simply said, an RDF link indicates that a piece of data has some relationship to another piece of data (Bizer et al., 2008). Linked data allows data to be linked and used within an SDI to improve data interoperability and accessibility. This implementation will utilize the system architecture as depicted in Figure 5. The country profiles are transformed into an applicable ontology by translating the Unified Model Language (UML) models into a Web Ontology Language (OWL) ontology model using Protégé. The required datasets for the ontology are created by extracting data from registers, transforming the data with SPARQL construct queries, and loading the data in a new dataset, by the construction of SPARQL queries 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.

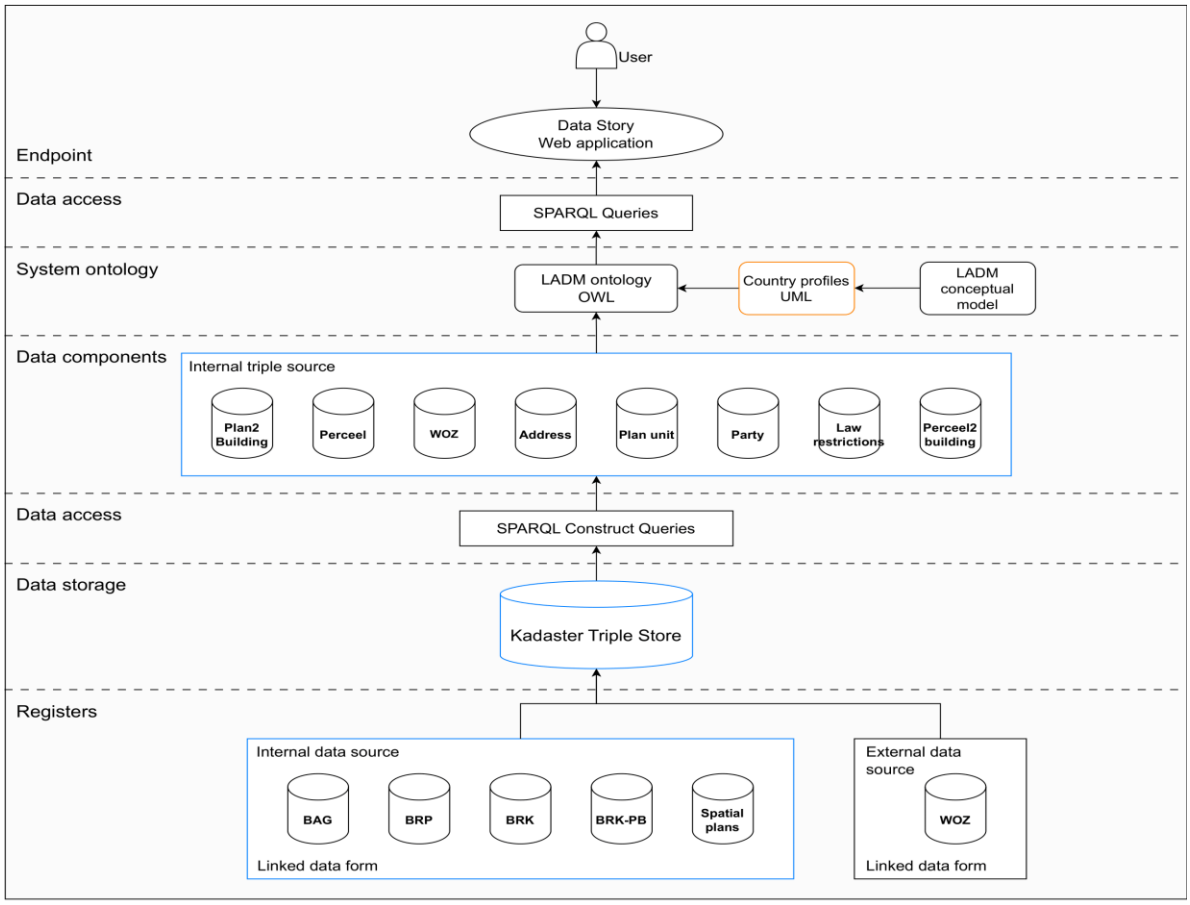

Figure 5. System architecture of implementation with linked data

During implementation, it was found necessary to establish a direct relationship between the SP_PlanUnit and LA_SpatialUnit classes, indicating that an SP_PlanUnit can include one or more LA_SpatialUnits, while an LA_SpatialUnit can be included in zero or more SP_PlanUnits. In the Netherlands, spatial plans require spatial data sources, so the cardinality to LA_SpatialSource was updated to 1..*, making the relationship mandatory. As a result, the SP_SubSpatialUnit class is no longer needed, and SP_PlanUnit and LA_SpatialUnit are merged into a new class, NL_SpatialUnit; see Figure 6.

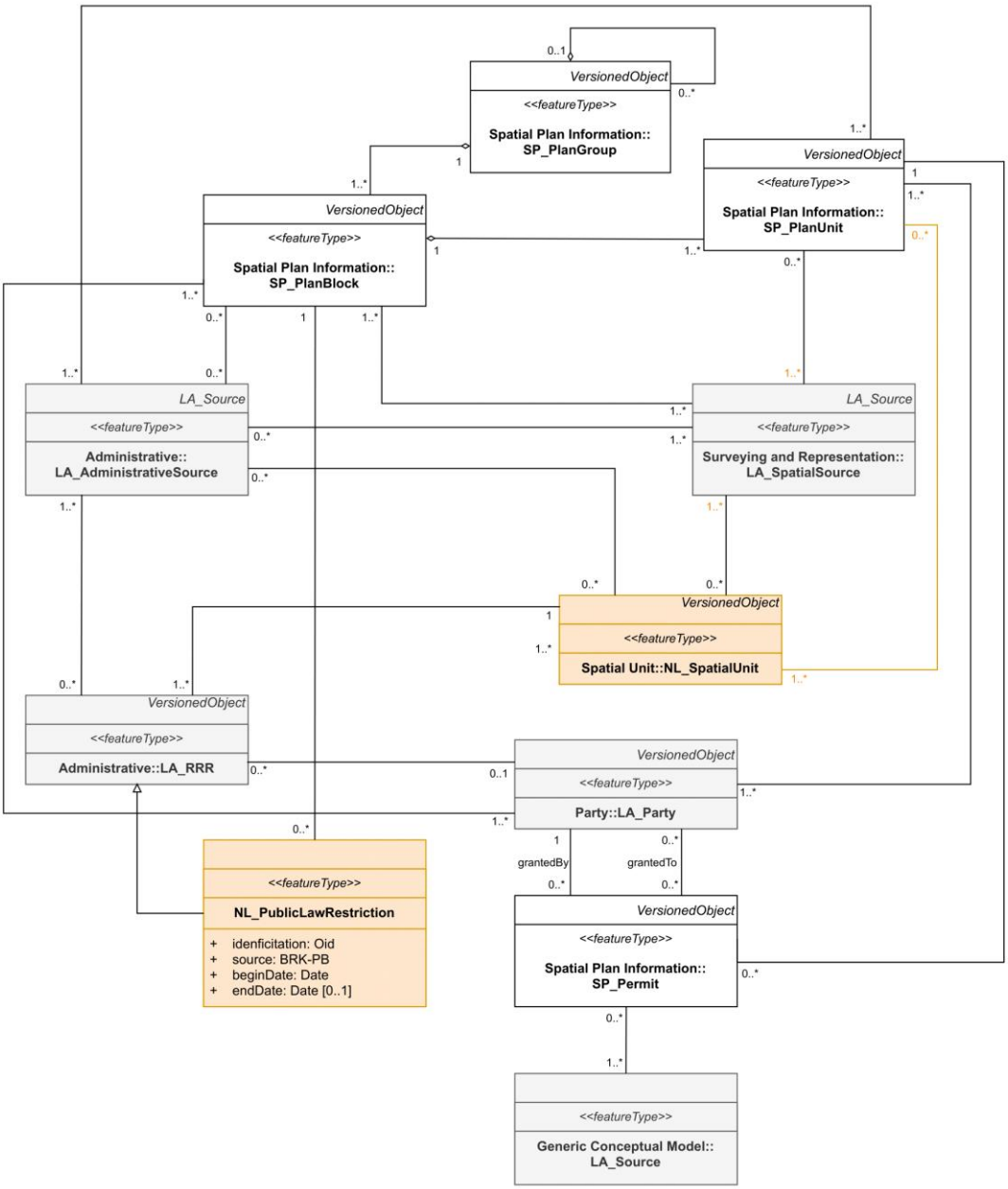

Figure 6. Country profile iteration

6. ASSESSMENT AND EVALUATION

To evaluate the use cases, a benchmarking approach is utilized, identifying various metrics to assess the performance of the prototype compared to the current situation. First is to decide on the relevant assessment criteria. 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 is 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).

Table 1. Assessment metrics

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 optimalization	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.

The figure 7 visualizes the assessment of these metrics. It shows which state of the use case, the current state or with 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.

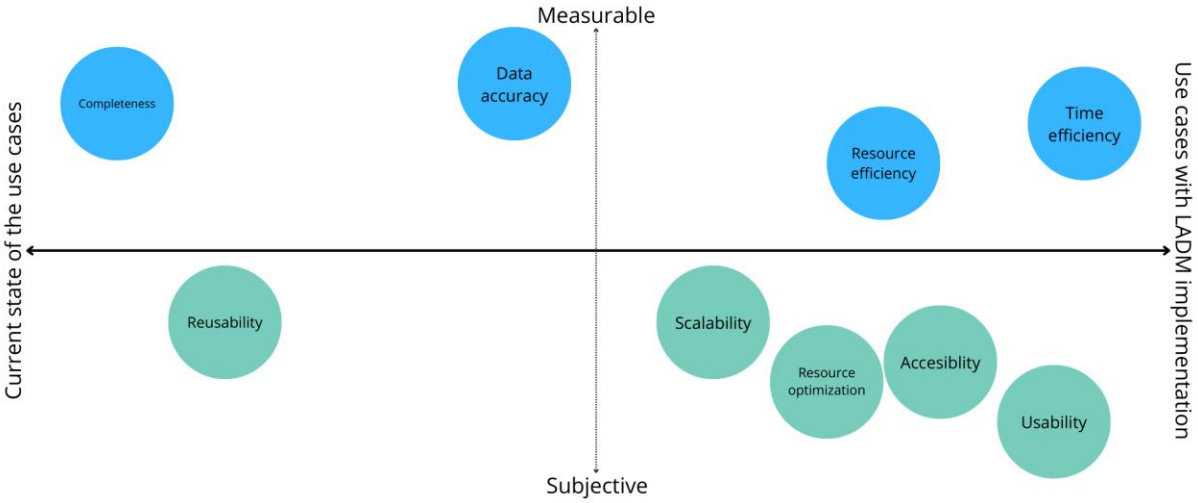

Figure 7. Visualization metric assessment

A small usability test with 6 users was conducted to evaluate the usability of the prototype portal. Usability testing is a method which enables to test the functionality of a product. 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). The purpose of the test is to guide the test users with clear explanations, to present the tasks to be performed, and to collect information about the usability through the users' answers. Due to time constraints it was decided to conduct the usability test focusing solely on the use case of a building permit. The findings indicate that users are able to complete the tasks and retrieve the required information, 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, and test users 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.

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. As the Netherlands LADM prototype only covered a part of the country and was also not updated, there is a preference for the current state of the use cases when considering the completeness, reusability and data accuracy of the data.

7. CONCLUSION AND FUTURE RESEARCH

This research can serve as an example of how multiple LADM parts are used to provide an harmonized land administration portal for users as tested in the Netherlands. It should be noted that the 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. Registers containing personal information could not be used due to privacy issues, so instead fake data

was used in this research in the development of the prototype. The country profile of the Netherlands reflects adaptations to address country specific needs. The class LA_BAUnit was merged with LA_SpatialUnit due to the lack of a distinction between these units in the Dutch system. Country-specific classes, such as NL_PublicLawRestriction and NL_SpatialUnitRestriction, were introduced to model, while NL_RegulatoryArea was added to define their application scope. Additionally, valuation information was tailored with country specific classes like NL_WOZ-value and NL_WOZ-object, reflecting the integration of property valuation practices. Simplifications and enhancements to the model improved its suitability for Dutch land administration, such as aligning the SP_PlanBlock class with NL_PublicLawRestriction to reflect land use planning.

A linked data implementation of the UML conceptual model used OWL ontologies to define system structures. Merging ontologies facilitated integration, while SPARQL construct queries created datasets. Iterative attribute validation revealed discrepancies between LADM attributes and Dutch registers, leading to adjustments in datasets. Relationships, such as between SP_PlanUnit and LA_SpatialUnit, were refined during implementation. Linked data enabled seamless integration of data from different registers, but such adaptations from standardized LADM attributes could hinder cross-border interoperability. The prototype data story demonstrated LADM's potential to enhance time and resource efficiency, usability, and accessibility by consolidating data into a single portal.

Table 2. Benefits and drawbacks of the prototype of a linked data portal based on the Land Administration Domain Model (LADM) Edition II concepts

Benefits	*Drawbacks*
Time efficiency	Validation of the country profile, including the attributes and code list
Resource efficiency	Creation of datasets conform the ontology
Usability benefits for the selected use cases	Data must be in linked data format (including writing of SPARQL queries for querying of the data)
Enables Kadaster to develop, implement and maintain land administration systems more efficiently	
Enables users to access information in a way that is clear and understandable to locals, foreigners and machines.	

The LADM-based approach enables efficient system development and maintenance, enhanced accessibility for locals and foreigners, and domain-specific standardization. Compatibility with INSPIRE and industry standards offers further benefits. However, significant challenges remain, including the need to validate country profiles, transform datasets into linked data, and

develop SPARQL queries. The time and resource investments required for implementation must be weighed against these benefits.

Future studies include:

- expand the scope of this research by incorporating more diverse and complex use cases, including underground (utility) networks, marine georegulation, and additional registers and geoportals
- further align LADM attributes with Dutch registers, populate all ontology classes with data, and evaluate usability and query performance.
- focus on cross-border interoperability, cost analysis, and balancing access to protected registers with privacy.
- feasibility of different implementation methods and international adoption of LADM should be explored.

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BIOGRAPHICAL NOTES

Marjolein van Aalst holds a Bachelor's degree in Industrial Design Engineering and a Master's degree in Geomatics, both from the Technical University of Delft in the Netherlands, and is currently working as a trainee in Information Management at Omgevingsdienst West-Holland.

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, the Netherlands. In 1990 he received a PhD from Leiden University. He is professor at the Delft University of Technology, Faculty of Architecture and the Built Environment, the Netherlands. He is co-chair of the FIG Working Group on 'LADM and 3D Land Administration'.

Alexandra Rowland obtained an MSc in Geographical Information Management and Applications from the University of Utrecht, the Netherlands in 2021 based on the thesis proposing a methodology for automatic GIS workflow generation using semantic technologies. Following graduation, Alexandra joined Kadaster, the Dutch Land Registry and Mapping Agency, as a PDEng student and is currently supporting the ongoing development of the Kadaster Knowledge Graph. Her research investigates the role that this Knowledge Graph and other linked data developments within the organisation could play in Kadaster's future data platform.

Erwin Folmer received his MSc in Technical Business Administration (Industrial Engineering) in 1999 at the University of Twente, based on a master thesis assignment on requirements engineering at Baan Development. From 1999 until 2001 Erwin was innovator at KPN Research involved in amongst other the order entry and billing systems of ADSL services. In 2001 Erwin joined TNO, and became senior scientist on the topic of interoperability and standards. From 2009 he part-time joined the University of Twente to start a PhD research on the standardization topic, while continuing his work for TNO. In 2012 received his PhD based on the 'Quality of Semantic Standards' thesis. In 2013-2014 Erwin was visiting researcher at ERCIS/University of Munster. From 2015 onwards Erwin joined Kadaster. At Kadaster he is leading the developments of the Linked Data platform for open geographical data. Currently this is the largest deployment of Linked Data in the Netherlands, and among the largest in the world. In 2024 he did discontinue his activities at the University of Twente and became lecturer at the HAN, University of Applied Sciences in Arnhem en Nijmegen.

Hendrik Ploeger studied law at Leiden University and the Free University of Amsterdam, The Netherlands. In 1997 he finished his PhD thesis on the subject of the right of superficies and the horizontal division of property rights in land. He is associate professor at Faculty of Architecture and the Built Environment, the Netherlands. His research expertise focuses on land law and land registration, especially from a comparative legal perspective.

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