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Implementation of the INSPIRE Directive in the context of Spatial Data Infrastructure development in the Czech Republic

by

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Declaration

I declare that I am the sole author of the dissertation thesis under the guidance of prof. Ing. Aleš Čepek, CSc.and Ing. Petr Souček, Ph.D.

All literature and other sources is mentioned in the Bibliography.

29th February, Prague

Abstract and contributions

This dissertation thesis deals with the problem of meaningful implementation of the INSPIRE Directive with respect to existing national spatial data infrastructures. Main goal is to publish data in a standardized structure and in a way that is useful for users already using the data on the national level and that actually brings advantages over national data sets.

In particular, the main parts of the dissertation thesis focus on design and development of functional implementation of INSPIRE data sets for themes Cadastral Parcels and Buildings. The solution is in the careful analysis of requirements and possibilities of both INSPIRE and national data sets and take into acount also the needs of the national users.

The outputs of the analysis are then used in the creation of the models (application schemas) and technical realization (XML schemas). The dissertation thesis lightly touches also transformation and publication of data itself and metadata records.

The main output of the work is functional design of implementation of two INSPIRE themes – Cadastral Parcels and Buildings – with respect to the needs of existing national users. Implementation of both themes is fully compliant with INSPIRE Data Specifications and XML schemas published by JRC and extends the content to the full potential given by original data.

Keywords:
INSPIRE, Cadastral Parcels, Buildings, data modeling, Geographic Mark-up Language, Spatial Data Infrastructure, SQL Database

Tato disertační práce se zabývá problémem smysluplné implementace Směrnice INSPIRE ve vztahu k již existujícím národním infrastrukturám prostorových dat. Hlavním cílem práce je publikace dat ve standardizované struktuře a způsobem, který je snadno využitelný stávajícími uživateli data na národní úrovni a který přináší výhody oproti současnému stavu národních datových sad.

Práce se zabývá především návrhem a vývojem funkční implementaci INSPIRE datových sad Parcely a Budovy. Součástí řešení je důkladná analýza požadavků a možností modelu INSPIRE i národních datových sad, včetně zahrnutí potřeb národních uživatelů dat.

Výstupy analýzy jsou použity při tvorbě modelů (aplikačních schémat) a jejich technických zpracování (ve formě XSD schémat). Disertační práce se okrajově zabývá také transformací a publikací dat a metadatovými záznamy.

Hlavním výstupem disertační práce je funkční návrh implementace dvou témat INSPIRE – Parcely a Budovy – s přihlédnutím k potřebám uživatelů, kteří doposud pracují s národními datovými sadami. Implementace obou témat je plně v souladu s datovými specifikacemi INSPIRE a se schématy XSD publikovanými JRC a rozšiřuje je o obsah národních datových sad.

Klíčová slova:

INSPIRE, Parcely, Budovy, datové modelování, Geographic Mark-up Language, infrastruktura prostorových dat, SQL databáze

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Special thanks go to the colleagues, especially to David Legner, Martin Šmejkal and Veronika Kůsová from Czech Office for Surveying, Mapping and Cadastre, and Martin Ledvinka, Petr Křemen and Miro Blaško from Czech Technical University in Prague. Special thanks to Martin Ledvinka is for the motivational master race who is going to finish first.

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Chapter 1

Introduction

1.1 Motivation and problem statement

This dissertation thesis focuses on providing and publishing the data in the frame of the Infrastructure for Spatial Information in Europe (INSPIRE) in the Czech Republic through the implementation of the Directive of the same name and extending the published information to satisfy needs of both national and European users. The implementation of the Directive has begun in 2007 and data sets of the Annex I had to be done in the end of 2017. Annexes II and III follows in October 2020. The most important part of this work was done in the most difficult time during the implementation of data sets of Annex I and one data set of Annex II. It should work as an approach for other providers, not to repeat the same mistakes and hopefully help them to understand that implementation of the INSPIRE Directive has to be treated not as obligation, but as an opportunity to enhance the quality and usability of the provided data.

The problem is, that INSPIRE is quite complicated to understand. It is trying to provide huge number of data sets, metadata records and services above both data and metadata, in a specific structure in order to publish machine–readable data using same standards across the whole European Union. But countries have developed national systems, that were working independently for a long time. Costs and effort spent to build them and keep them working was enormous. Most of the countries already provides data sets thematically belonging to the INSPIRE Directive, but using totally different structure, and in many cases published in much more detailed form. That is consequence of simplification of data models to contain information provided by every country. This was huge problem e.g. in the case of Cadastral Parcels, where different law for each country is applied. The main problem this thesis is going to solve is to design a data models fulfilling all INSPIRE requirements and respecting its structure on one side, and containing all the data needed by national users on the other side.

1.2 Goals of the dissertation thesis

Main goal of the work is to enhance the data model, setup transformation and discoverability of data harmonized and published according to the INSPIRE Directive in the Czech Republic to be better used by both government bodies and citizens. It is known, that some of the most valuable features and attributes for the users are not present in the INSPIRE models, therefore INSPIRE data are not used much by the national bodies. Improvement of its usability is done in three steps.

First step is the analysis of the current situation, content of INSPIRE Data Specifications for specific themes (topics associating data based on its content) and partly INSPIRE Technical Guidelines on Metadata and Web Services (describing the standardization of data publishing methods and description of data and services providing the data), availability of the data in the local databases in the context of existing Spatial Data Infrastructure on the national level (including its publication and description) and also the needs of the users. Important part of the analysis is also gathering resources providing same or similar data in non-INSPIRE way and analysis of its contents, structure and usability by their users. The heavily used data sets are in the center of interest for the further work.

Second step exploits the results of the Analysis. Based on the intersection between INSPIRE Application schemas described in Data Specifications and already provided national data arises the new model – application schema – with respect to both. In practice, the INSPIRE model is being extended in this step. That requires also technical representation ina form of XML Schema Definition[3]. This representation allow data providers to generate data in certain structure and users to validate their data against it. The whole second step is described as modelling.

Final step of the process is transformation of the data using mapping into the model structure and publication of the data. Usually, both transformation and publication are done by specialized software. The goal of the process is to transform the data in a way that uses its full potential. Quality is improved by increasing the availability and/or usability of the data, metadata or services used for publishing the data. Though, metadata and services may be only enhanced since the data exists.

1.3 Outputs of the dissertation thesis

Work is based on the implementation of two INSPIRE themes within the resort of the Czech Office for Mapping, Surveying and Cadastre – Cadastral Parcels and Buildings. Based on the processes mentioned above (and described in the rest of this work), INSPIRE data models were enhanced to contain all the important information that are part of national data sets covering those themes and that are normally used by the national users of the data. The publication of the data was enhanced by creating the functional way of publication data using Atom Service. Discoverability of the data was improved by simplification of simple and more accurate keywords, creating improvised thesaurus and improving machine readability by approaching to the linked data standards using URIs as identifiers and more smaller details, such as marking the resource as open data or INSPIRE harmonized resource. The outputs of the data modelling and extending the schemas is a set of XML Schema Definitions (XSD) for application schemas Buildings Extended Base, Buildings Extended 2D, Cadastral Parcels Extended and creation of auxiliary XSD for types used at Czech Office for Surveying, Mapping and Cadastre. In the proposal there is a wide usage of URI identifiers, causing the creation of local open registry of code lists and code list values related to the topics of real estates, addresses and territorial identification.

1.4 Structure of the dissertation thesis

The work is divided into several chapters. First chapter called background (2) describes the INSPIRE Directive, its principles and how is it transposed into the Czech legislation. Transposition of the Directive raised the need for coordination body and hierarchical governmental structure to ensure the smooth implementation of the Directive. For the implementation was set up the implementation plan (road map) setting dates for completion of the partial implementation steps. Status of the implementation of the INSPIRE Directive according to the road map is also part of the background, together with implementation processes. Implementation itself depends on the current spatial data infrastructure, that differs across member states, but also across the institutions in one country. Technical implementation follows Technical Guidelines and Data Specification Documents. Their importance is described further in the background section, including the standards referenced in these documents.

Next chapter, analysis 3, basically covers the first step on the way to achieve the main goal of this work. It provides very detailed view on the content of INSPIRE Data Specifications on themes Cadastral Parcels and Buildings, technical realization of the application models in a form of XML Definition Schemas and also the analysis of the national data sets covering the topics described in the INSPIRE Data Specifications. The content of the data sets is described in a part of the Data Specification called "Data content and structure", defining the content of the data set. Based on the application schemas, search for the national data corresponding to the Data Specification is performed. The results are analyzed in two ways – based on the content of data itself and based on the existing data sets used for national purposes. Last factor to be considered is the real needs of the users. In general, well processed national data set is more usable and decreases the need of more complex or complicated implementation of INSPIRE data[1]. Data are therefore analyzed in a further context, concerning content, form, publication and description – altogether called Spatial Data Infrastructure (SDI).

[1]But the goal of transforming the data into the structure given by INSPIRE remains.

Chapter 4 covers second step to achieve the main goal of this work – modelling – and also a part of the third step – transformation of data. Based on the analysis, the data sources are gathered and mapped into the data model. The outputs of this Chapter are application schemas for extended data models and XML Schema Definition documents. Models have to extend INSPIRE application schema and respect all requirements form the Data Specification document for the extended application schema. Part of the work described in this Chapter is dedicated to the mapping of the newly cerated model to the source of national data.

The process of the data publication is described in the chapter 5. It briefly describes needed step of a publication of the data, including description of data and services by metadata. However, processes described in this Chapter are not new and are present mainly for the completeness of the whole work. More information about the data publication and metadata are in the [4],[5].

Three previously described chapters contains the description of processes on the creation and implementation of theme Buildings, using application schema Buildings Extended 2D, and theme Cadastral Parcels with extensions, using application schema called Cadastral Parcels Extended. Chapter 6 describes what was actually done in this work, assuming the reader have understood the rest of the text.

1.5 Tools used

Data of the Czech Office for Mapping, Surveying and Cadastre are stored in Oracle Database using Oracle Spatial for storage of geographic information. For the modeling, software tools yED and Modelio were used in general. For some diagrams was used Oracle SQL Developer Data Modeler. Data from the database are transformed into GML 3.2.1 using software Marushka® by Geovap. For design, development and validation of both XML (including GML extension) and XSD files, Oxygen Editor was used. Oxygen has implemented validators Saxon EE and Xerces. For the validation of Web Feature Service, small standalone program in Python language was written. All material with informational purpose including this dissertation thesis were plotted in LaTeX.

Chapter 2

Background

This chapter reveals the basics of the whole work, refers to the scientific, legal and technical sources and builds the basis for analysis, modelling and transformation of the INSPIRE data extension upon required INSPIRE implementation. Chapter includes two sections: INSPIRE Directive and Implementing Rules and standardization. First section defines the goal of the project, describes legal documents associated with INSPIRE Directive and status of the implementation in the Czech Republic. It describes the structure and processes of implementation on the governmental level, defines the impact of INSPIRE and sums up the development level of national spatial data infrastructures. Second section shows the structure of technical documents (Implementation Rules represented by Technical Guidelines documents, that are only recommended) in relationship to the international standards (ISO and OGC).

2.1 INSPIRE Directive

INfrastructure for **SP**atial **I**nfo**R**mation in **E**urope (INSPIRE) is an initiative of the European Commission and Council. The Directive of the same name focuses on creating European legal framework needed to creation of the European Spatial Data Infrastructure. *The INSPIRE Directive aims to create a European Union spatial data infrastructure for the purposes of EU environmental policies and policies or activities which may have an impact on the environment. This European Spatial Data Infrastructure will enable the sharing of environmental spatial information among public sector organisations, facilitate public access to spatial information across Europe and assist in policy-making across boundaries. INSPIRE is based on the infrastructures for spatial information established and operated by the Member States of the European Union. The Directive addresses 34 spatial data themes needed for environmental applications.*[1]

[1] Source: `http://inspire.ec.europa.eu/about-inspire/`

Figure 2.1: Official logo of the INSPIRE project

2.1.1 Legal status of INSPIRE

As cited above, INSPIRE aims to unify the spatial data of Member states of the European Union. In order to achieve this goal, a few basic principles were defined [6]:

- Data should be collected only once and kept where it can be maintained most effectively.
- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.
- It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.
- Geographic information needed for good governance at all levels should be readily and transparently available.
- Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

The Directive came into force on the 15th May 2007. Since then, the process of the implementation among the Member states is running. Implementation is governed by a road map. Road map follows the articles of the Directive and attaches them the milestone dates. The whole road map is available at `http://inspire.ec.europa.eu/inspire-roadmap/`, some of the important milestones are listed in table 2.1.

Article	Milestone date	Description
6(a)	03/12/2011	Metadata available for spatial data sets and services corresponding to Annex I and Annex II
16	19/11/2011	Discovery and view services operational
7§3, 9(a)	23/11/2012	Implementation of Commission Regulation (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services for Newly collected and extensively restructured Annex I spatial data sets
6(b)	03/12/2013	Metadata available for spatial data sets and services corresponding to Annex III
7§3, 9(b)	21/10/2015	Newly collected and extensively restructured Annex II and III spatial data sets available
7§3, 9(a)	23/11/2017	Implementation of Commission Regulation (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services for other Annex I spatial data sets still in use at the date of adoption
7§3, 9(b)	21/10/2020	Other Annex II and III spatial data sets available in accordance with IRs for Annex II and III

Table 2.1: Some of the important milestones in the INSPIRE implementation road map.

Data are structured into 34 thematic data sets, divided into three Annexes. Data sets belonging to different Annexes have different dates of implementation. Full implementation is required in the year 2021. The main goal of the INSPIRE implementation is the creation of interoperable data sets corresponding to the valid Data Specifications for specified themes, its publication according to the Technical Guidelines and international standards and the description of data and services using standardized metadata records following Technical Guidelines and international standards. Other goals of INSPIRE implementation are creation of national Spatial Data Infrastructures, licensing of the data and services, sharing the data and monitoring and reporting [7]. None of the documents used within this part of the implementation is required by the INSPIRE Directive, only recommended by the Directive itself, but countries have transposed it into their national legislation in two years after the Directive came to force [8]. Czech Republic has transposed INSPIRE Directive into national legislation by the Act No. 380/2009 Sb., amending the Act No. 123/1998 Sb., on information about environment and Act No. 200/1994 Sb., on surveying.

Joint Research Center at the European Commission (JRC) recommends creation of national coordination bodies, supervising the implementation of the Directive in member states. Supervisor for the implementation of INSPIRE Directive in the Czech Republic is the Ministry of Environment. The advisory body of the Minister for the Environment – Coordination Committee for INSPIRE (KOVIN) – was founded for the purpose of implementation of INSPIRE Directive, evaluation of progress in the global goal of implementation, analysis of results of implementation and coordination of obligatory providers of spatial data. Partial goals are responsibility of Technical Working Groups under KOVIN. Technical Working Groups focus on parts of implementation of INSPIRE Directive, such as data, services, metadata, licensing, quality, monitoring, legislation or education. Technical Working Groups are open for everyone, including private subjects [9]. Implementation of the specific spatial data themes is done at the national level. KOVIN entrusts a guarantee for every spatial data theme. His goal is to coordinate other data providers and to publish data and services of the entrusted topic. This way is not very efficient, because it is very difficult to entrust someone who does not cooperate. For themes with bigger amount of national providers is very difficult to even start with implementation.

Organization responsible for progress of implementation is Czech Environmental Agency (CENIA). CENIA covers most Technical Working Groups, manages web pages about Czech INSPIRE implementation and in particular manages National Geoportal for INSPIRE [2]. National geoportal is important place serving as the exchange point of spatial information (including data, services and its description) between national publishers and Europe. CEINA is using the Geoportal to ensure the accessibility to the data and network services based on spatial data, sharing the spatial data in public administration and informs about the usage of Spatial Data Infrastructure. To easily achieve the main implementation goals, the national Strategy for INSPIRE implementation was created since beginning of 2014. Strategy was authorized by the Minister for Environment in June 2015. Main reasons for creating the Strategy was inefficient funding of fulfilling the requests of INSPIRE Directive on national, regional and local level. As the main goal of the Strategy was set the creation of national INSPIRE Spatial Data Infrastructure as a part of European Infrastructure and as a support tool for fulfilling environmental politics on regional, national or European level. Implementation of the strategy should have ensured easier access to bigger amount of data sources and its reuse by various user groups [10]. Current state of the implementation has change quite a lot since the creation of Strategy, but it may be caused by oncoming deadlines according to the road map.

2.1.2 Status of implementation in Europe and Czech Republic

Part of the INSPIRE implementation is regular monitoring and reporting of the status of the implementation. Reports are collected by national coordinators and sent to the Joint Research Center to evaluate. Evaluation is based on four main fields of INSPIRE

[2] http://geoportal.gov.cz/

Directive: metadata, spatial data sets and services, network services and data sharing. Monitoring takes place every year, following mainly quantitative approach. European Commission expects as many data sets and services to be published as possible, but does not emphasize the quality of the data. Some countries (Czech Republic among them) have stopped providing big amount of data to European Geoportal, because the content and structure of the data had nothing to do with INSPIRE Directive. Those countries had immediate decrease in evaluation in annual INSPIRE monitoring. As an addition to the monitoring, once in three years, INSPIRE implementation is evaluated within INSPIRE reporting, following qualitative approach. Last report of the European Commission to the European Council and Parliament is from 2016. Decrease of spatial data sets, network services and their metadata described above is mentioned as one of the main problems (90 % of all files are reported by only 8 countries), but it is stated that decrease of number of files may be caused by consolidating more data sets into one and in that case it is a positive phenomenon. This is not a case of the Czech Republic (or only partly). Decrease of data reported from the Czech Republic was caused by better control mechanism of what is reported to European geoportal. On the other side, data reported from the Czech Republic are considered of very high quality [11]. In 2014, mid-term evaluation was created. The summary of the mid-term evaluation results on the implementation itself (for the whole Europe) are:

- the implementation of INSPIRE is being done with some delay and non-uniformity, but in line with expected costs and benefits,
- not as much data sets as expected are documented with INSPIRE–compliant metadata (77 % of Annex I, which had been fully documented in 2011),
- there is a good progress on view and discovery services, but only 27 % of all data sets is available for both view and download,
- indicators show only limited progress in implementation of Annex I data sets, but only a small percentage of all data sets were referred as not 'new or heavily reconstructed', which were required in 2012,
- data sharing is based mainly on the public consultation, but results show that there is a widespread view (83 % of respondents) that INSPIRE has contributed to more open data policies in public sector [12].

Note that everything listed above comes from 2014, todays situation is a little bit different (and overall better).

Part of the Strategy for INSPIRE implementation in the Czech Republic is a SWOT analysis of strengths and weaknesses of the implementation in the Czech Republic. SWOT analysis is easily used on spatial information recognition area [13]. Strengths are mainly discover services and valuable experience from the implementation of the Register of territorial identification, addresses and real estates (RIAN) in 2012. Thanks to RIAN, most data for the implementation of INSPIRE themes Addresses, Buildings, Cadastral Parcels and Administrative Units were already unified in one functional system [14][15]. Among the weaknesses there are mainly funding and technical difficulty of the implementation requiring the usage of international standards (ISO and OGC). On the other side, it is only good for the authorities to start using international standards and not only for INSPIRE implementation, but over all government infrastructures. This is also apparent from the opportunities part of SWOT analysis. Threads are mainly low priority of SDIs in the Czech government and insufficient education of employees in government technically implementing INSPIRE [10]. In the beginning of 2018, SDIs still have low priority, and apparently, open data infrastructure as a whole, managed by the Ministry of Interior, still have low priority as well.

In the middle of 2017, there where 140 relevant data sets and data set series registered on INSPIRE geoportal for the Czech Republic, where 21 are series. INSPIRE Geoportal [3] is managed by JRC. In the first quarter of 2018, there were only 135 records altogether, but 24 series. In the end of 2018, new version of Geoportal was launched and it is no more possible to distinguish between data sets and series. In the very end of 2019 there was 151 records altogether for the Czech Republic. Based on the assumption that only data set series are downloadable via INSPIRE download services, it may be estimated 26 series out of all 151 records. That confirms European trend described above. The reasons in the Czech Republic are similar to the reasons in the rest of Europe. As more INSPIRE conform data sets are published, original national data sets are no more harvested to the European Geoportal. Among the series, there are present data for the following INSPIRE themes:

Title	Managed by	Status
Geographical grid systems	Land Survey Office	Data are accessible through ČÚZK Geoportal [4] through view service and download service using ATOM for ETRS89-LAEA and ETRS89-GRS80 without fees.
Geographical names	Land Survey Office	Accessible through ČÚZK Geoportal 4, data are operated by view service (no fees), or paid download service using WFS or direct download of map lists via e-shop.

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[3]http://inspire-geoportal.ec.europa.eu/

[4]http://geoportal.cuzk.cz/

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Title	Managed by	Status
Administrative Units	Czech Office for Surveying, Mapping and Cadastre	Data are accessible through download service operated by WFS and ATOM, view service operated by WMS and direct download of one file containing the whole Czech Republic, everything for free. Provided data are open data.
Addresses	Czech Office for Surveying, Mapping and Cadastre	Data are accessible through download service operated by WFS and ATOM, view service operated by WMS and direct download of files containing data for municipalities, everything for free. Provided data are open data.
Cadastral Parcels	Czech Office for Surveying, Mapping and Cadastre	Data are accessible through download service operated by WFS and ATOM, view service operated by WMS and direct download of files containing data for cadastral zonings, everything for free. Provided data are open data.
Transport networks	Land Survey Office	Data are published according to the type of traffic (road, water, cable, rail, air) through ČÚZK Geoportal 4. View service (via WMS) is without fees, download service (via WFS) is paid and accessible through e-shop.
Hydrography	Land Survey Office	Accessible through ČÚZK Geoportal 4, data are operated by view service (no fees), or paid download service using WFS or direct download of map lists via e-shop.
Land use	Individual regions	Some regions publish INSPIRE harmonized data for land use. It is supposed to have one harmonized series of data sets over the whole Czech republic.
Orthoimagery	Land Survey Office	Accessible through ČÚZK Geoportal 4, data are operated by view service (no fees), or paid download service using WCS or direct download of tiles from e-shop.

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Title	Managed by	Status
Buildings	Czech Office for Surveying, Mapping and Cadastre	Data are accessible through download service operated by WFS and ATOM, view service operated by WMS and direct download of files containing data for municipalities, everything for free. Provided data are open data.

Table 2.2: Implementation of INSPIRE themes

All series of data sets listed above are discoverable through national and European geoportals. Timetable of publication of INSPIRE themes is visible in the figure 2.2.

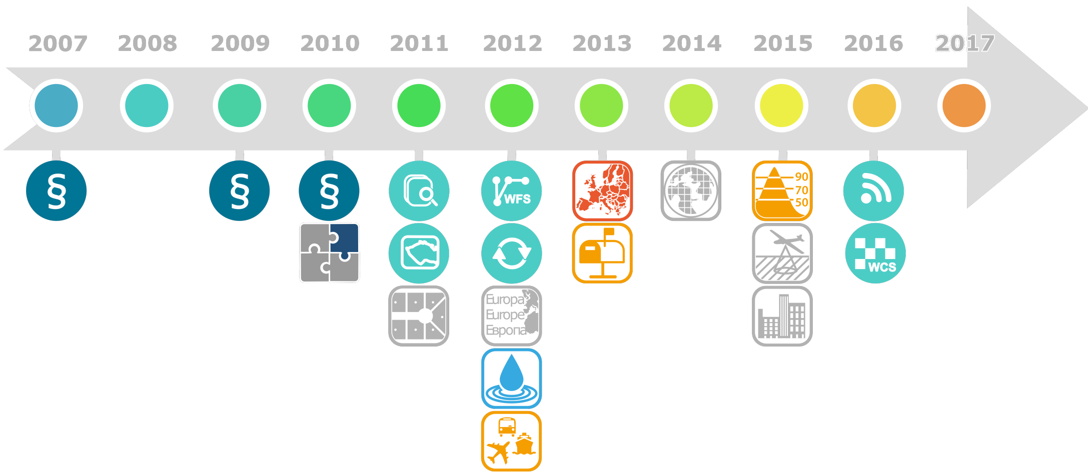


Figure 2.2: Timetable of publication INSPIRE data and its services. Source: Veronika Kůsová, Land Survey Office

Discovery Service via Catalogue Service for the Web (CSW) and View Service via Web Map Service (WMS) were implemented in 2011 together with data and metadata of INSPIRE theme Cadastral Parcels (CP). In 2012, Download Service via Web Feature Service (WFS) was implemented for Cadastral Parcels, Transformation Service via Web Coordinate Transformation Service (WCTS) and implementation of data, metadata and View Service of the INSPIRE themes Geographical Names (GN), Hydrography (HY) and data and metadata of Transportation Networks (TN). In the following year (2013), INSPIRE themes

Administrative Units (AU) and Addresses (AD) were fully implemented and Transportation Networks (TN) and Geographical Grid Systems (GGS) were published using View Service via WMS. In the year 2014, INSPIRE theme Geographical Grid Systems (GGS) was finished upon full implementation[5] and data of all already published data were made available via Web Feature Service (WFS). Following year (2015) brought full implementation of three INSPIRE themes – Elevation (EL), Orthoimagery (OI) and Buildings (BU). Orthoimagery is using Web Coverage Service (WCS) for Download Service implementation. In 2016, some of the existing INSPIRE data were published via ATOM feed and Web Coverage Service (WCS). WCS is used in version 1.0, that is not fully compatible with Geography Markup Language (GML) in version 3.2.1. and therefore is not fully interoperable. Some other INSPIRE themes are not applicable in the Czech Republic (e.g. Maritime zones), others are not implemented yet.[6]

Note that most of implemented data and services were implemented in the department of Czech Office for Surveying, Mapping and Cadastre[7] and Regional offices. Regional Offices are publishing usually more than one data set per region within spatial data theme Land Use (LU). Guarantee for this INSPIRE theme is Ministry for Regional Development, but the implementation was done by regions themselves until first quarter of 2018. Moreover, resources have usually 0.00 % level of interoperability with INSPIRE. That does not mean that they are not interoparable at all – there is usually major problem in the first part of interoperability testing, that does not allow the testing to continue. As mentioned above, it is expected to aggregate more national data sets into one INSPIRE data set series per topic in the future, but according to the latest informations from the end of march 2018, Ministry of Regional Development wants to create separate methodology for INSPIRE and non-INSPIRE data. This is generally considered as a wrong decision within the INSPIRE community, because it goes against the INSPIRE principles.

Content of data sets and series of data sets listed on the European Geoportal is usually related to certain INSPIRE theme, but nor the data neither their publishing are often corresponding to the INSPIRE requirements, or they represents data harmonized to the rules of other European projects. Those data sets are usually source data for non-harmonized Spatial Data Services. Good example of this practice in the Czech Republic may be Fundamental Base of Geographical Data (ZABAGED®), partly covering topics Buildings, Land Cover, Transportation Networks, Hydrography, Land Use and Protected Sites, but the data are not INSPIRE interoperable and do not even intend to. In the case, that some theme is not implemented yet, national data set containing the data of the topic shall be harvested to INSPIRE Geoportal instead, e.g. Land Cover in the ZABAGED® case.

[5] GGS is reference theme containing two source data sets – Grid_ETRS89-LAEA and Grid_ETRS89-GR80

[6] Implementation of the extensions of Buildings and Cadastral Parcels are described in this dissertation thesis.

[7] Land Survey Office is part of the department.

Most of the data set series listed above are published using network services mentioned in INSPIRE Directive. Those services shall be able to discover, transform, view and download spatial data [7]. A brief description of the services follows:

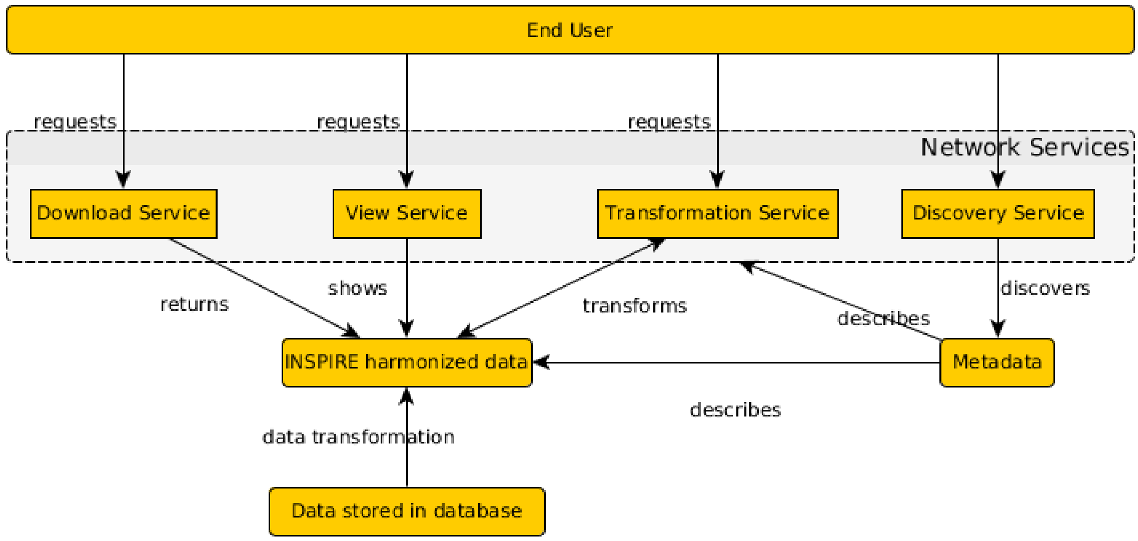


Figure 2.3: Basic relations between data, services and metadata.

- Discovery service – serves as a catalogue service for discovery of the metadata. Catalogue services may be associated in larger catalogues, e.g. INSPIRE Geoportal contains a discovery service searching across national catalogue services of Member states. Providers of the data and services publishes metadata and harvests them to national geoportal, where catalogue service is running over the metadata. Harvesting metadata through national geoportal is in the scope of the operator of national geoportal – CENIA. Anyway, there is a possibility of providing metadata directly from local Discovery service, evading the central body. Common consensus in the Czech Republic is to harvest all records via national geoportal.

- Transformation service – allows transformation of INSPIRE data from one coordinate reference system to another. The ETRS89 reference system is required by INSPIRE Directive, but most of the member states are using custom national coordinate reference system. Transformation service for transformation between various map projections of ETRS89 and Czech national S-JTSK was implemented by Land Survey Office and is accessible from `http://geoportal.cuzk.cz/Default.aspx?mode=`

TextMeta&text=wcts&menu=191. Various projections of the coordinate reference system are supported, such as Lambert Azimuthal Equal Area, Lambert Conformal Conic or Transverse Mercator.

- Download service – serves for enabling copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly [7]. Every authority providing data is usually also responsible for providing the download service over those data. Technical implementation of download service differs according to the amount of provided data, format of the data and purpose for downloading the data.

- View service – making it possible, as a minimum, to display, navigate, zoom in/out, pan, or overlay viewable spatial data sets and to display legend information and any relevant content of metadata [7]. Every authority providing data is usually also responsible for providing the view service over those data. Many providers extends the minimum requirements listed above by get feature info operation and supports multiple formats.

The common network services model is described in the Figure 2.3. Data, usually stored in local databases, are transformed into INSPIRE harmonized structure and content data. This is usually being done once in a time period (e.g. Land Survey Office in the Czech Republic transforms data for INSPIRE using the extract, transform, load – ETL – method for transformation of data usually twice a year) or continuously. Continuous transformation may be used by live access to the data, or more sophisticated by continuous updates of predefined data set files. Already harmonized INSPIRE data are described by metadata and accesses by download, view and transformation services. All the services are also described by metadata documents. All the metadata records are available by Discovery Service. National Geoportal harvests accessible data and services through Discovery Service. The certain metadata records are harvested from the national geoportal to the INSPIRE geoportal on the European level. This geoportal is managed by European Commission, specifically by JRC.

The INSPIRE Directive defines few groups of services 2.4. In the meaning of European Spatial Data Infrastructure, Spatial Data Services, that are regulated by IR Interoperability, are all services, that are at least invocable and are provided with metadata. Services not meeting these conditions are called Other Spatial Data Services. The service is invocable if it is available via access point on the internet. If the service is invocable, it shall contain more detailed information in the metadata record, e.g. operations details, supported coordinate reference systems etc. Spatial data services (SDS) regulated by Regulation 1089/2010 are further divided into three different levels of interoperability: invocable SDS , interoperable SDS and harmonised SDS. All SDS s established and operated according to the Art. 11 of INSPIRE Directive are Network services. All network services shall meet requirements form regulation 976/2009 [16][17] In this dissertation thesis, all services are considered as Network Services, unless stated otherwise.

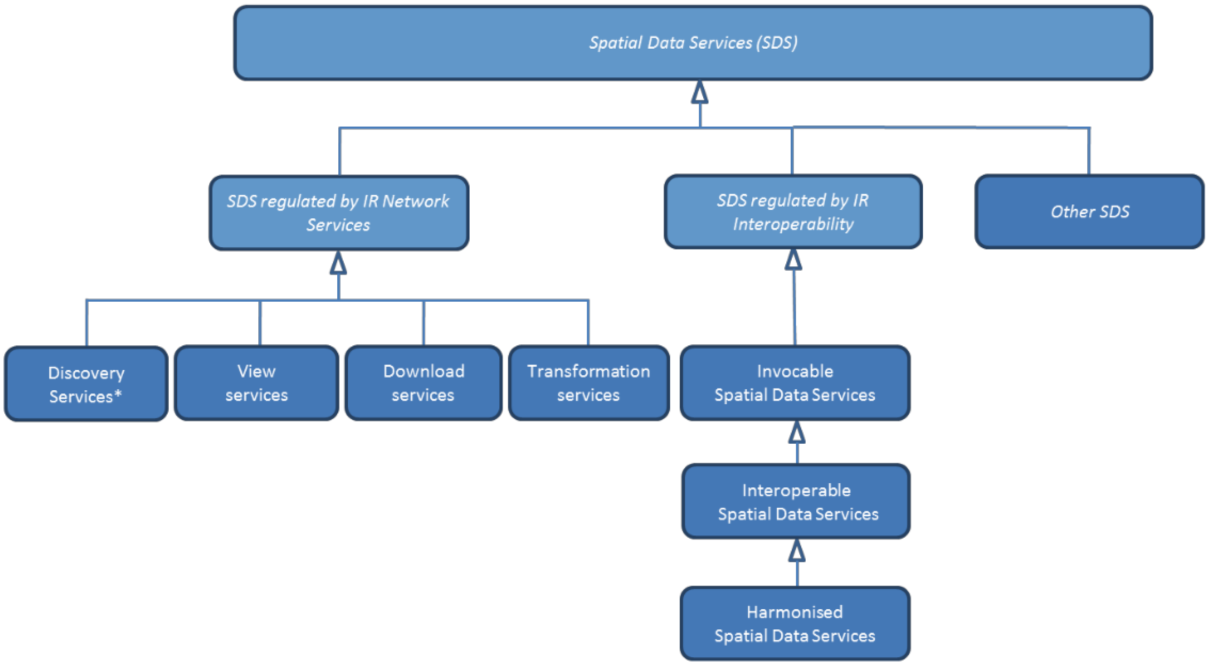


Figure 2.4: Services types according to the European Spatial Data Infrastructure. Source: Technical Guidance for the implementation of INSPIRE data set and service metadata based on ISO/TS 19139:2007 in version 2.0.1 from 2nd March 2017.

2.2 Implementing Rules and standardization

To ensure that European Spatial Data Infrastructures are going to be usable in compatible form, INSPIRE Directive requires the adoption of common Implementing Rules (IR) in several specific areas. Most important for the implementation in the context of development of SDI are implementing rules on metadata, interoperable spatial data and harmonized network services. Implementing Rules are realized through Technical Guidelines on Metadata, Technical Guidance on Network Services and Data Specifications of specific INSPIRE spatial data themes. Implementing Rules are not obligatory for the member states by European law. All member states have transposed INSPIRE Directive into national legislation, which have made the Implementation rules compulsory for member states by their own law. Implementing Rules contain Requirements and Recommendations. Requirements are crucial to validation of data and services, without its fulfillment the metadata are not valid, data are not harmonized and services are not interoperable network services. Recommendations shows an ideal case, but may be done otherwise or not at all without any impact on the validity of the result.

The current Technical Guidelines document on Metadata is in version 2.0.1 from March 2017, but in most cases it has not been yet put in practice. Most of the current metadata records available via Discovery Service are compliant with version 1.3 of Technical Guidelines on Metadata from November 2013[8]. Both version are based on ISO standards 19115 for metadata of spatial data sets and series of data sets and 19119 for metadata of spatial data services. Most of the changes are fixing leeks discovered during the implementation process or are trying to move the implementation closer to the linked data by using Uniform Resource Identifiers (URI) instead of character string properties. Implementation of metadata in the Czech Republic follows National Metadata Profile, that fully implements INSPIRE Metadata Profile described in Technical Guidelines on Metadata, that is extended by national specifics. Rules defined in National Metadata Profile are always more strict than those in Technical Guidelines and rules in Technical Guidelines are always more strict than ISO profiles. Technical Guidelines define the elements appearing in metadata, describe them and map them to the elements of ISO profile. Cardinality or content is also specified in the Technical Guidelines more strict than in ISO profiles. The current version of Technical Guidelines on Metadata [16] are transposed into Czech metadata profile in its version 4.0.are transposed into Czech metadata profile in its version 4.0.

Spatial Data themes are described in Data Specifications. Data Specifications specify data models as the application schemas, code lists and portrayal rules for view services for every theme. Data Specifications were written by INSPIRE Thematic Working groups for specific themes. Some themes are described more detailed than others, but all Data Specifications maintain certain standard. Differences in approach are caused by character of a topic and similarities in natgional legislation on current topic in member states. Data Specifications are stand alone documents. Every specification contains Overview, briefly subscribing content and mapping to the Implementing Rules. Most important chapter for the implementation is Data Content and Structure. It contains overview of application schemas according to the ISO 19109:2015 Geographic Information – Rules for Application Schema. ISO 19109 defines application schema as "conceptual schema for data required by one or more applications"[18]. Most of the themes have one application schema, some are more complex offering more application schemas and/or their combination. Example of such theme is Buildings from Annex II. Data Specification on Buildings describes six application schemas (as seen in Figure2.5). Two semantic Application schemas are abstract. Practical schemas extends abstract schemas by obligatory geometry. In the case of Buildings, application schemas are created as a combination of semantic model (Base and Extended) with geometry representation (2D or 3D). New application schema can be created by extending existing one with full respect to its contents. INSPIRE extensions must involve INSPIRE required content and documentation of extension (e.g. by UML schema). Those rules for extending INSPIRE schemas are described in Annex F of INSPIRE Generic Conceptual Model – a document from 5th April 2013[19].

Data Specification document also specifies:

[8]Althought metadata according to the version 2.0.1 were available for Monitoring and Reporting for some data sets.

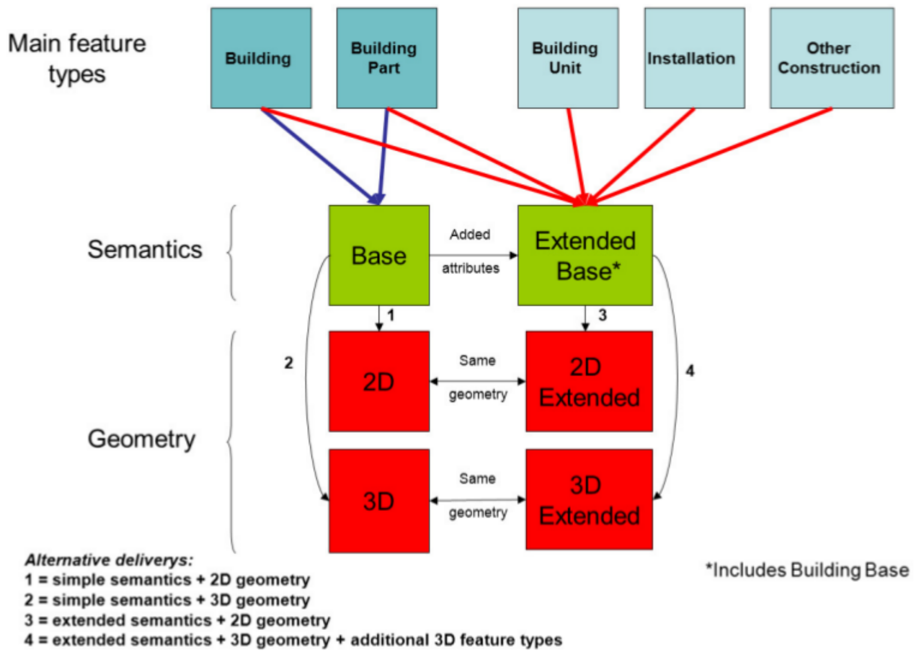


Figure 2.5: Application schemas from the Data Specification on Buildings[1].

- obligatory reference coordinate systems,
- required data quality by using set of pre–defined tests,
- additional rules on metadata (besides obligatory elements declared in Technical Guidelines on Metadata),
- delivery of data including the update period,
- specific guidance to data capture and portrayal defining the styles of data visualization in View Service.

Vector data in INSPIRE are typically represented using the Geography Markup Language (GML) in version 3.2.1 according to the Open Geospatial Consortium (OGC) standard [20]. Standard defines XML grammar designed for expression of geographical objects. Structure of the spatial data model according to the application schemas is described by XML Schema Definition (XSD) documents containing definitions of elements, types and constraints. XSD documents are used for validation of the data in order to ensure the compliance of INSPIRE requirements.

Format of raster data is defined in the delivery section of Data Specification on relevant themes (e.g. Orthoimagery uses TIFF and/or JPEG2000 for raster representation).

Implementation Rules for Network Services are divided according to the network service type into four documents – Technical Guidance for the implementation of INSPIRE View Services in version 3.11 from April 4, 2013, Technical Guidance for the implementation of INSPIRE Download Services in version 3.1 from August 9, 2013, Technical Guidance for the implementation of INSPIRE Discovery Services in version 3.1 from November 7, 2011 and Technical Guidance for the INSPIRE Schema Transformation Network Service in version 3.0 from July 12, 2010. Few other documents describes special types of implementation of INSPIRE Network Services, e.g. Technical Guidances for the implementation of INSPIRE Download service using Web Coverage Service (WCS) or Sensor Observation Service (SOS).

Technical Guidances on Network Services extends ISO profiles according to the ISO standards provided mostly by technical group ISO/TC 211, on Geographic information. Relevant ISO standards reuse OGC standards (as seen in the Figure 2.6), such as WMS and WMTS for View Service, WFS and WCS for Download Service, CSW for Discovery Service or WCTS for Transformation Service. Some services also uses non-OGC standards (e.g. Atom Publishing Protocol).

Mapping of INSPIRE Technical Guidance to the OGC standards is ambiguous and document–specific. Technical Guidances define Conformance Classes. INSPIRE Conformance Classes are mapped to the ISO, OGC or other standards conformance classes or their parts and define the parameters of the service, format of the data, distribution units etc.

Figure 2.6: INSPIRE Implementation Rules are mapped to the ISO Profiles. ISO Profiles from the ISO/TC 211 are mapped to the OGC standards.

Quality of the service defines the capacity of the service, its availability and its performance. It is important to notice, that minimal requirements are quite low, lower than the minimal expected traffic of a service of a similar magnitude (e. g.View Service requires to allow at least 20 requests per second, but real traffic on the WMS services of a similar magnitude in the Czech Republic is much higher). Setting the service to the minimal requirements of INSPIRE would lead to the crash of the service [21].

Close connection of INSPIRE Implementing Rules to the ISO and OGC standards is caused by the need of sharing similar data (or data describing similar phenomenons) with guaranteed quality across the huge amount of different platforms. Most of the data described in the INSPIRE Data Specifications are already published by the member states as national data sets, but the content, structure and quality of the data differs country to country according to the national legislation, data storage, used software etc. Those differences are large enough to make sufficient exchange of the information impossible. Data models created in order to standardize and unify national data sets had to be simplified, which makes them practically useless for the wider national use. To capture the full potential of the data in national data sets, data has to be extended in some way. Only the reuse of the INSPIRE standards and proper documentation of the extension make data based on extended models INSPIRE compatible, easy to share across EU and detailed enough to be used on the national level at the same time. The consistency of the data to the INSPIRE Implementing Rules helps users from other European Countries, data analysts and developers. Extensions of the data models allow national users and re–users to get all the information they need in a standardized format with known structure, published through standardized services.

Chapter 3

Analysis

One of the main goals of the work is to compare data models based on Data Specifications with existing national data sets covering INSPIRE themes Buildings and Cadastral Parcels. That requires analysis of the Data Specification documents and currently published national data sets. To accomplish another goal of the work – designing a data model valuable for both national and European usage – it is also important to analyze needs of the users on the national level[1]. These three tasks are presented in the following sections.

3.1 Spatial data set models in INSPIRE

As written in section 2.2, data models of INSPIRE are described in Data Specification documents mainly in the section "Data content and structure". Data Specifications presents application schemas. Application schema models creates functional parts of the data sets. It is not neccessary to implement all of them, e.g. it is possible to implement application schemas Buildings base and Buildings base 2D and skip all 3D and extended application schemas for the theme Buildings as it is shown in the Figure 2.5.

Each INSPIRE Data Specification document shows overview of available application schemas and then detailed description of each application schema including visualisation of data model in UML and detailed description of feature types, their attributes, used data types or constraints. It does not set the representation of the output data, such as used format, attribute names, mapping etc. Yet, there are XSD files for most application schemas published on the INSPIRE web at the location `https://inspire.ec.europa.eu/schemas/`. Those schemas define feature types with their attributes including data types compatible with GML 3.2.1 format and most of the INSPIRE validators expect the final data from member states in this encoding and format, even using this serialization. Technically it should be possible and valid to publish INSPIRE data sets using different schemas and formats.

[1]Current data models for INSPIRE data are considered European needs in this dissertation thesis.

This work is focused on the data of the INSPIRE themes Buildings and Cadastral Parcels in the Czech Republic and in both cases, various different problems resulting into the need of designing new XSD schemas were encountered. Therefore it is crucial to describe feature types of Buildings and Cadastral Parcels in this dissertation thesis, although they are properly described in the Data Specification documents.

3.1.1 Buildings Data Specification document analysis

Data Specification document for Buildings presents six application schemas as seen in Figure 2.5 in the previous chapter. The creators of the Data Specification from the INSPIRE Thematic Working Group *Buildings* extended the possibilities of the data providers according to the semantic and spatial detail of provided data. There are two levels of semantic detail and two levels of geometry available. The hierarchy of the schemas is following:

- ***base schema*** contains feature types with basic semantics with no geometry,
- ***extended base schema*** imports base schema, adds detailed semantics with no geometry,
- **2D schema** imports base schema adding 2D geometry,
- **extended 2D schema** imports extended base schema adding 2D geometry,
- **3D schema** imports base schema adding 3D geometry,
- **extended 3D schema** imports extended base schema adding 3D geometry.

All semantic non-spatial information are present in the base and extended base schemas. Additional geometry is added in application schemas 2D, 3D, extended 2D and extended 3D.

Application schema models are shown as UML diagrams further in the text. Note that feature types and data types defined in the base schema are shown in blue color and types defined in extended schema are beige. Feature types and data types defined in 2D and 3D (Core) schemas are light green and those defined in extended 2D and extended 3D are yellow.

3.1.1.1 Buildings base application schema

Base schema UML overview is shown in the Figure 3.1. As seen in the picture, it includes four abstract feature types: ***AbstractConstruction***, ***AbstractBuilding***, ***Building*** and ***BuildingPart***, one main data type **BuildingGeometry2D**, which is not used within defined feature types and few other data types and code lists. Application schema Buildings Base has no concrete feature type, therefore it is considered abstract schema. Types listed above are considered main types according to the Data Specification. On top of that,

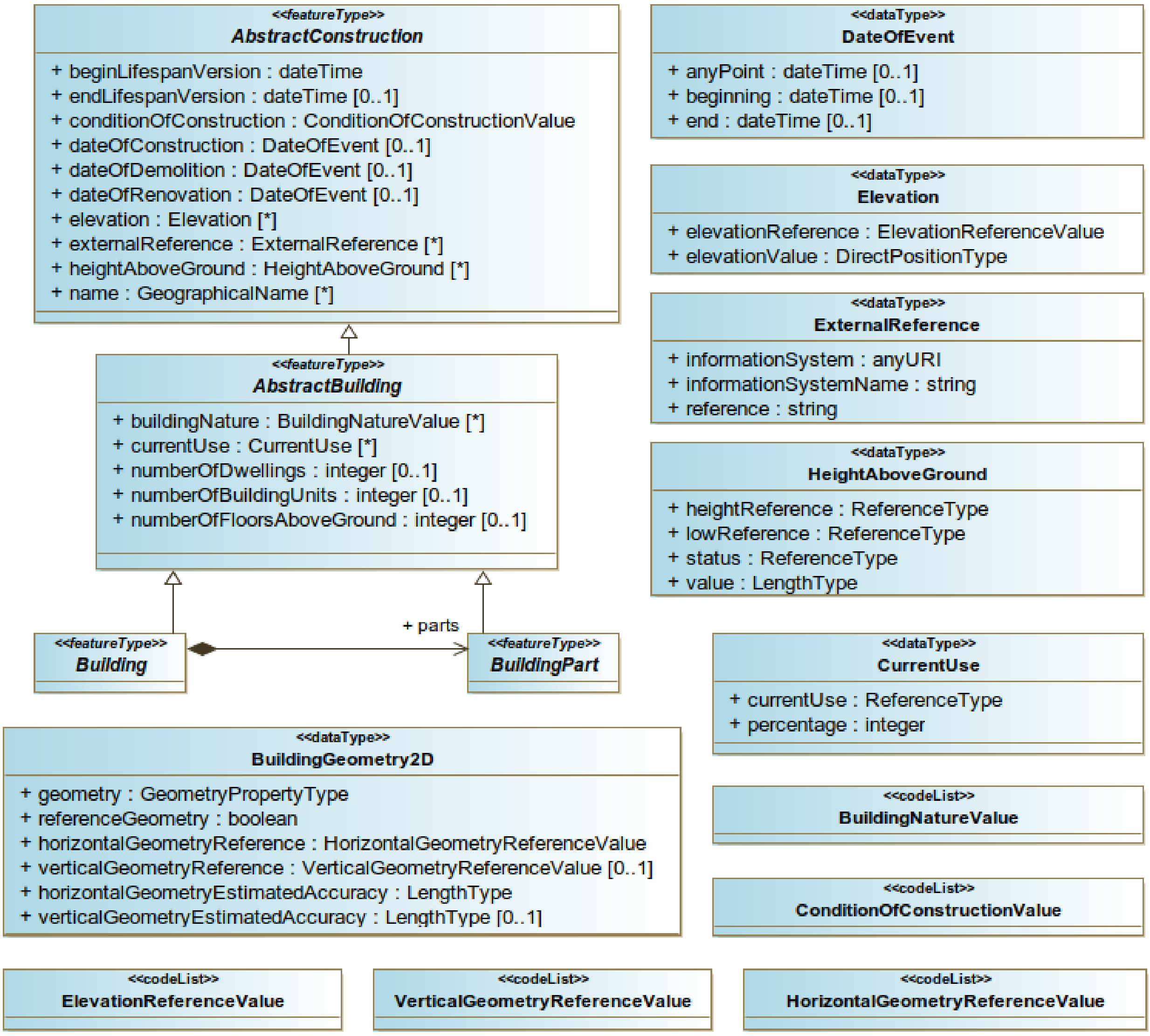


Figure 3.1: Buildings base schema UML overview – feature types, data types and code lists.

data types **Elevation**, **HeightAboveGround**, **ExternalReference**, **DateOfEvent** and **CurrentUse**, altogether with code lists **BuildingNatureValue**, **ConditionOfConstructionValue**, **ElevationReferenceValue**, **VerticalGeometryReferenceValue** and **HorizontalGeometryReferenceValue**, belong to the base application schema.

AbstractConstruction is a feature type representing basic construction of any type without geometry. It has only one mandatory attribute – `inspireId`. All attributes are described here:

- `inspireId` – identify object uniquely in the data set, so the object may be addressed from other INSPIRE themes,
- `beginLifespanVersion, endLifespanVersion` – lif ecycle of the object within the data set,
- `conditionOfConstruction` – status of the construction, acquires a value from code list (projected, underConstruction, functional, ruin, demolished, declined),
- `dateOfConstruction` – date of construction of the object in the real world,
- `dateOfDemolition` – date of demolition of the object in the real world,
- `dateOfRenovation` – date of renovation of the object in the real world,
- `elevation` – property containing information about the elevation, i.e. vertical distance from well-defined surface commonly taken as origin, and information on how it was measured,
- `externalReference` – reference to external information system, that shall be used for accessing additional information about the object,
- `heightAboveGround` – height of the object from the ground level to the top of construction,
- `name` – name of the construction if any (such as London Eye, Schwarzenbersk palc).

Basic information about the construction includes state of the object, its lifespan in both model and real world and basic information including its shape (heightAboveGround) and position (elevation). Absence of geometry on this level is caused only by the complex nature of geometry representation in data model, taking into account more possibilities of geometry representation among various data providers.

AbstractBuilding assumes that object may be already identified as a building with possible floors, parts and units as well as it is meant to be used in a certain way. Its attributes (all voidable) are listed below:

- `buildingNature` – contains value from a code list defining its nature. It may be based on its shape, size and/or function (castle, church, tower etc ...). Nature is usually meant for showing object in the map,
- `currentUse` – contains information about the function of the building (residential, agricultural etc ...) and is meant to fulfill management requirements,
- `numberOfDwellings` – dwelling is basic residential unit consisting of one or more rooms, such as flat or household,

- `numberOfBuildingUnits` – building unit is a part of a building, that is accessible from outside, functionally independent and may be sold separately, such as shop inside a shopping centre, flat, garage etx ...
- `numberOfFlorsAboveGround` – number of floors above ground (i. e. no underground floors).

It is crucial for data transformation to determine objects as building units or dwellings. Both dwelling and building unit may differ among member states according to the national legislation. Also the number of floors above ground may become problem in some cases, especially when building is located in the hillside.

Building and ***BuildingPart*** are model representations of buildings and their parts, where building is defined as enclosed construction above or under ground, used for intended shelter or for the production. Building may be simple or composed with building parts. Building part is subdivision of building that may be considered as building itself. Understanding objects as buildings or their parts is a basic assumtion for data modeling of INSPIRE Buildings. The only association role of these feature types is `parts` – a link between building and its part or parts.

Data types defined within the application schema are used to express more complex values of the attributes. **DateOfEvent** provides beginning, end or any point within the range of event. **Elevation** provides value of elevation itself and a reference to where the elevation has been captured. **ExternalReference** provides reference to external system in a form of URI and name of remote system and identifier of construction within that system. **HeightAboveGround** provides information about height of the object, as a difference between elevation at ground level and the top of construction. **CurrentUse** provides information about use of building including of percentage of a building used described way. Code lists provide information about nature of a building and condition of construction. **BuildingGeometry2D**, although not used within buildings base schema, provides geometry representation of a building in two dimensions, including estimated accuracy.

Base schema defines building and its part with basic attributes, that defines building based on shape and (non–geometric) location, functionality, status and lifespan. Data modeled according to the base application schema is sufficient for basic overview of buildings in landscape and distribution according to the basic attributes. Taking into account the obligation to publish data sets according to the INSPIRE Directive, base schema allows mandatory providers to fulfill the obligation technically quite easy for relatively low effort. Anyway, wider analytical use of data set is not really possible and use of extended base schema is more suitable.

3.1.1.2 Buildings extended base application schema

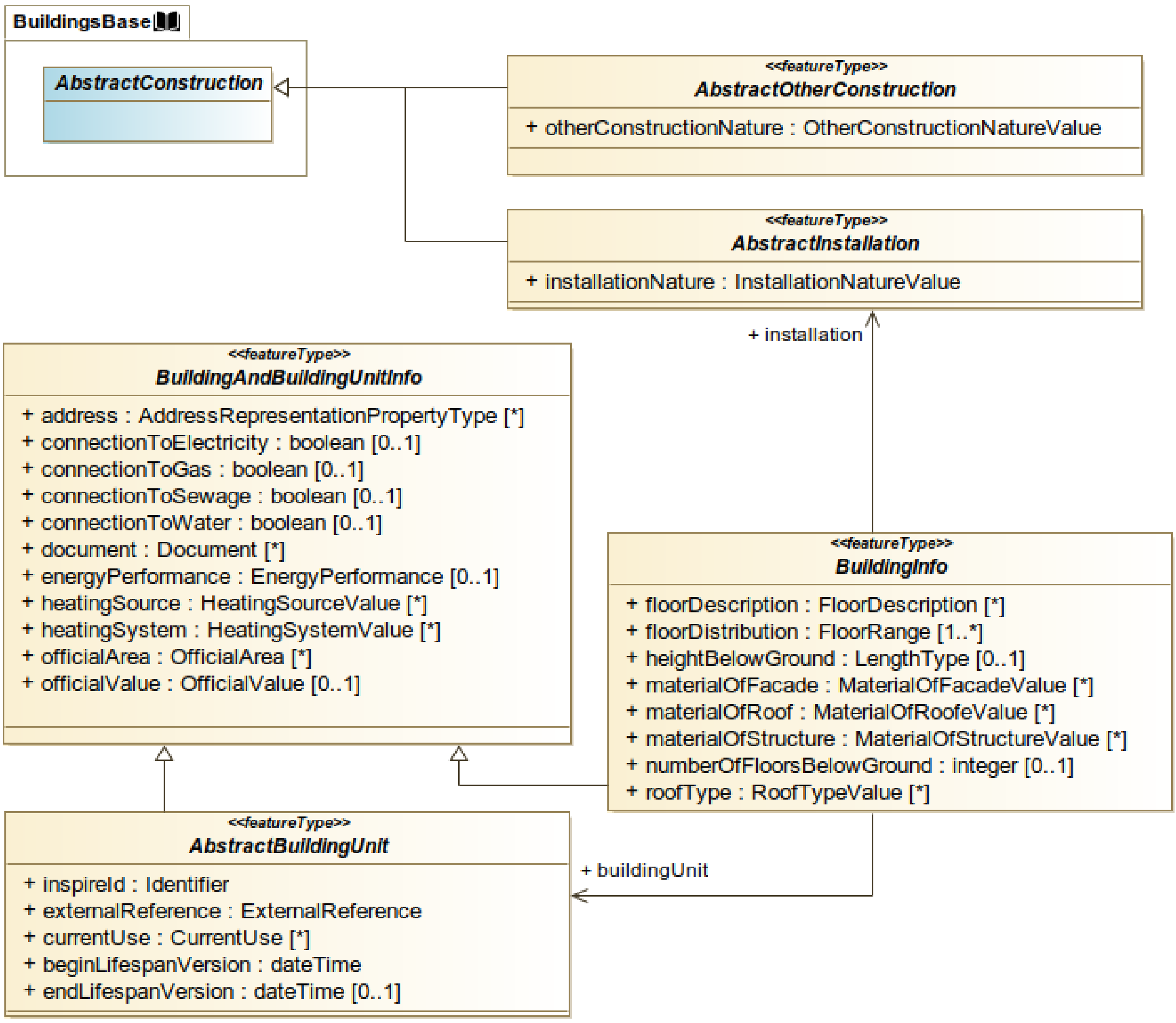


Figure 3.2: Buildings extended base schema UML overview – feature types.

Extended base schema is much more complex, adding multiple information about buildings and their parts and new construction types. Moreover, most of the attributes are optional. That allows every provider to publish only relevant data or data available in the national data stores. Yet, several possible problems were identified during the analysis of extended base schema. View at the UML schema of extended base feature types in the Figure 3.3 gives the idea of the content – five new feature types, two of them reusing ***AbstractConstruction***. UML schema in Figure 3.3 shows data types and code lists. Newly defined feature types are ***AbstractOtherConstruction***, ***AbstractInstall-***

ation, ***BuildingAndBuildingUnitInfo***, ***AbstractBuildingUnit*** and ***BuildingInfo***. Data types are, as for Buildings base schema, more complex data types for attributes used within present feature types. Those data types are **Document**, **EnergyPerformance**, **OfficialArea**, **OfficialValue**, **FloorDescription** and **FloorRange**. Moreover, few attributes shall contain a value from a code list. The following code lists are defined in extended base schema: **HeatingSourceValue**, **InstallationNatureValue**, **MaterialOfFacadeValue**, **HeatingSystemValue**, **MaterialOfRoofValue**, **MaterialOfStructureValue**, **RoofTypeValue** and **OtherConstructionNatureValue**.

Feature types ***AbstractOtherConstruction*** and ***AbstractInstallation*** are specializations of ***AbstractConstruction*** from Buildings base schema and are attribute base for feature types **OtherConstruction** and **Installation** from Buildings extended 2D and Building extended 3D schemas. Other construction is a construction, that is not considered as building, but it is necessary to describe landscape and to fulfill use cases such as safety or spatial planning, as said in the specification. Typical example of other construction is a chimney, bridge, self standing antenna, fence or wall, tunnel etc. Installation on the other side is a construction that is attached to the building or its part. Typically it may be antenna, chimney, balcony, external lift or stairway or air conditioning unit. In the Czech Republic, neither of these types is present in the data sources for buildings.

Both feature types contain only one attribute:

- `otherConstructionNature` – attribute of ***AbstractOtherConstruction*** containing a value from code list **OtherConstructionNatureValue**, that defines the nature of other construction,

- `installationNature` – attribute of ***AbstactInstallationValue*** containing a value from code list **InstallationNatureValue**, that defines the nature of installation.

Other three feature types are modeled unusually. Neither of them is a specialization of any feature type defined in Buildings base schema. Moreover, multiple inheritance problem appears further in the model for Buildings extended 2D and Buildings extended 3D schemas. Even the name of the feature type – ***BuildingAndBuildingUnitInfo*** refers more to the information about building or building unit object, than building or building unit object itself. ***AbstractBuildingUnit*** is an abstract feature type defining building units – subdivision of buildings with own lockable access from outside or from a common area, that is not another building unit. It is important to note that building unit is independent and may be separately sold or rented. ***BuildingAndBuildingUnitInfo*** collects all additional properties of both buildings and building units. Properties specific for buildings or building units alone are within feature types ***BuildingInfo***, respectively ***AbstractBuildingUnit***.

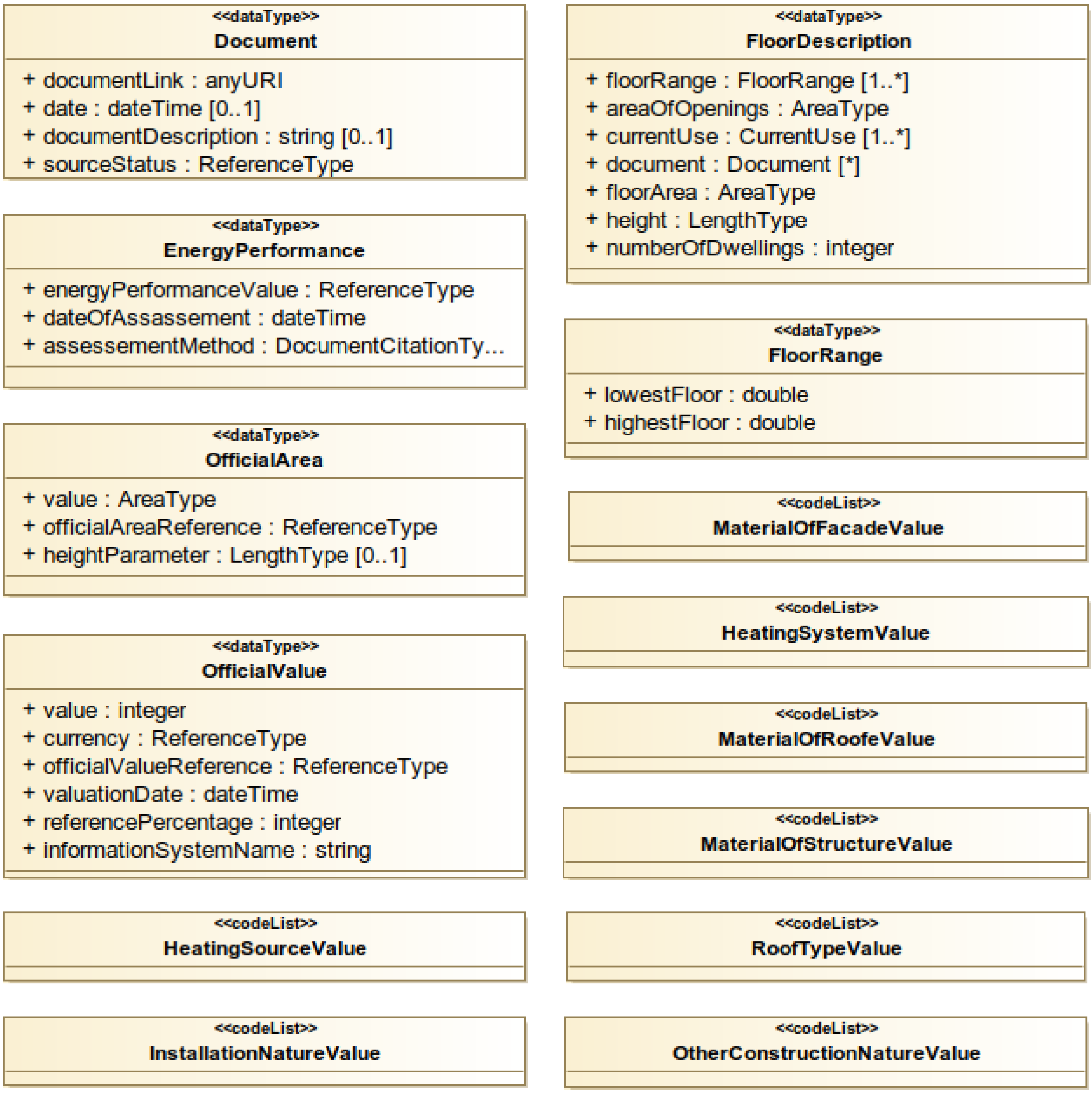


Figure 3.3: Buildings extended base schema UML overview – data types and code lists.

Feature type ***BuildingAndBuildingUnitInfo*** contains following attributes:

- `connectionToElectricity` – boolean indicator of connection of building or building part or building unit to public electricity network,
- `connectionToGas` – boolean indicator of connection of building or building part or building unit to public gas network,

- `connectionToSewage` – boolean indicator of connection of building or building part or building unit to public sewage network,
- `connectionToWater` – boolean indicator of connection of building or building part or building unit to public water network,
- `document` – attribute containing any document providing more information about the building or building part or building unit, e.g. buidling permit, photo of facade, emergency plan etc.,
- `energyPerformance` – energy performance of the building or building part or building unit, which is required for new buildings being rent or sold by the Energy Performance of Building Directive,
- `heatingSource` – source of energy used to heating, e.g. natural gas, electricity,
- `heatingSystem` – system of heating, e. g. stove, heat pump, central heating,
- `address` – attribute providing current address of the building or building unit in the structutred data type defined in theme Addresses,
- `officialArea` – official area of the building or building part or building unit,
- `officialValue` – official value of the building or building part or building unit.

The feature type ***BuildingAndBuildingUnitInfo*** also contains two association roles: `cadastralParcel` and `address`, providing links to the cadastral parcel and address to which the building or building unit is officially related. It is important to notice that association role `address` may contain link to the address provided in the INSPIRE theme Addresses, while attribute `address` shall contain the whole address as a Address type from the INSPIRE theme Addresses.

Feature type `BuildingInfo` is an abstract feature type containing building or building part specific attributes of the extended model:

- `heightBelowGround` – height of the underground part of building or building part,
- `numberOfFloorsBelowGround` – number of underground floors of building or buidling part, including underground parking, cellars etc.,
- `floorDistribution`, `floorDescription` – range of floors of the building or building part and its description,
- `roofType` – shape of roof, acquires the value from a code list **RoofTypeValue**,
- `materialOfFacade`, `materialOfRoof`, materialOfStrucutre – materials of facade, roof and structure, acquire the values from a code lists.

The feature type **BuildingInfo** also refers to `buildingUnit` and `installation` via association roles. None of the attributes applying to this feature type apply to the building units.

On the other hand, feature type ***AbstractBuildingUnit*** is an abstract object type containing semantic properties of building units only, inheriting general attributes from ***BuildingAndBuildingUnitInfo***. Basically, ***AbstractBuildingUnit*** contains attributes, that identifies building unit and its lifespan in a similar way those attributes are defined in base schema for building and building part. Building unit is not considered construction and does not inherit from ***AbstractConstruction*** feature type. Specific attributes for building units are:

- `inspireId` – identifies object uniquely within data set,
- `currentUse` – activity hosted by the building unit,
- `externalReference` – external information system reference, containing additional information about the building unit,
- `beginLifespanVersion`, `endLifeSpanVersion` – life cycle of the object within teh data set.

Budilding units divide buildings into smaller units treated as separate entities in a daily life. Examples of building units are shops within the commercial center or appartments within comdominium. According to the national regulations even flat, cellar or garage may be trated as building unit. Some entities may be both building and building unit (e.g. single family house). It is up to the national providers if it is considered as a building composed of one or zero building units.

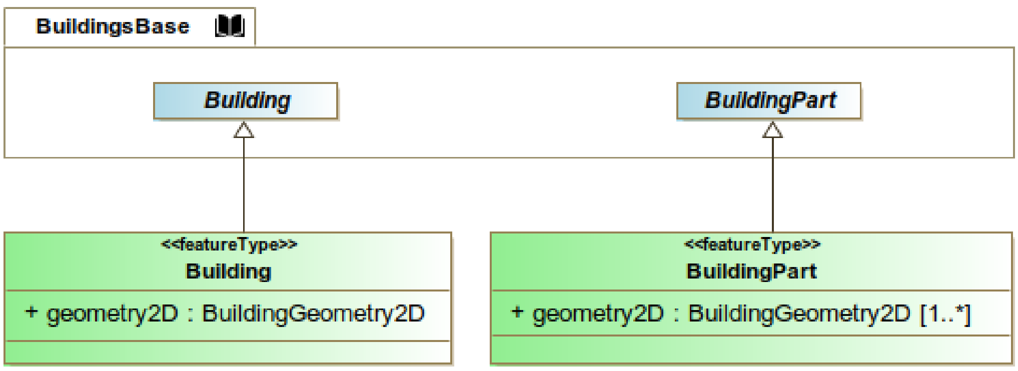


Figure 3.4: Buildings (Core) 2D schema UML overview.

Both base and extended base schemas contain only abstract features with semantic attributes and no geometry. The specific classes inheriting from abstract classes of base and extended base schemas are present within four application schemas. All of them are really simple. Their goal is to take semantic attributes altogether with representation of geometry to create specific classes. Application schemas are divided by the level of semantic detail and the dimension of geometry representation.

3.1.1.3 Buildings 2D application schema

Buildings 2D (or Core 2D, as is also named in the Data Specification document) have specific classes **Building** and **BuildingPart** inheriting from Buildings base schemas abstract classes ***BuildingsBase::Building*** and ***BuildingsBase::BuildingPart***[2], as seen in the Figure 3.4. Both have only one attribute:

- `geometry2D` – for the representation of 2D geometry, **BuldingsBase::Building-Geometry2D** data type is used.

While **Building** has exactly one geometry representation, **BuildingPart** may have more. Data type **BuildingsBase::BuildingsGeometry2D** is restricted to Simple Features v1.2.1 as defined by OGC document [22]. For both feature types exactly one geometry representation must be a reference geometry, meaning that `referenceGeometry` attribute of **BuildingsBase::BuildingGeometry2D** must be set to `true`. Both feature types may have multiple representation of geometry, e.g. polygon and point geometry representation.

3.1.1.4 Buildings extended 2D application schema

Feature types **Buildings2D::Building** and **Buildings2D::BuildingPart** with their geometry and semantic attributes are parents of **BuildingsExtended2D::Building** and **BuildingsExtended2D::BuildingPart**, feature types representing building and building part in Buildings extended 2D schema, as seen in the Figure 3.5. Moreover, both **BuildingsExtended2D::Building** and **BuildingsExtended2D::BuildingPart** inherits also from ***BuildingsExtendedBase::BuildingInfo***, to inherit all the extended semantic attributes described in 3.1.1.2. This causes the multiple inheritance problem. In the XML language, for which are the schemas provided directly by JRC, multiple inheritance creates ambiguity in data structure and must be solved in the modelling. More about multiple inheritance problem and its solutions is in the section 4.2.1.1.

Thanks to the inheritance from Buildings 2D schema, both building and building part contain all the semantic information from the Buildings base schema and also 2D geometry representation. All the extended attributes are ensured by the inheritance from

[2]As the whole paragraph speaks about Buildings 2D schema, feature types and data types from other schemas are written in the form **OriginalSchema::FeatureTypeName**.

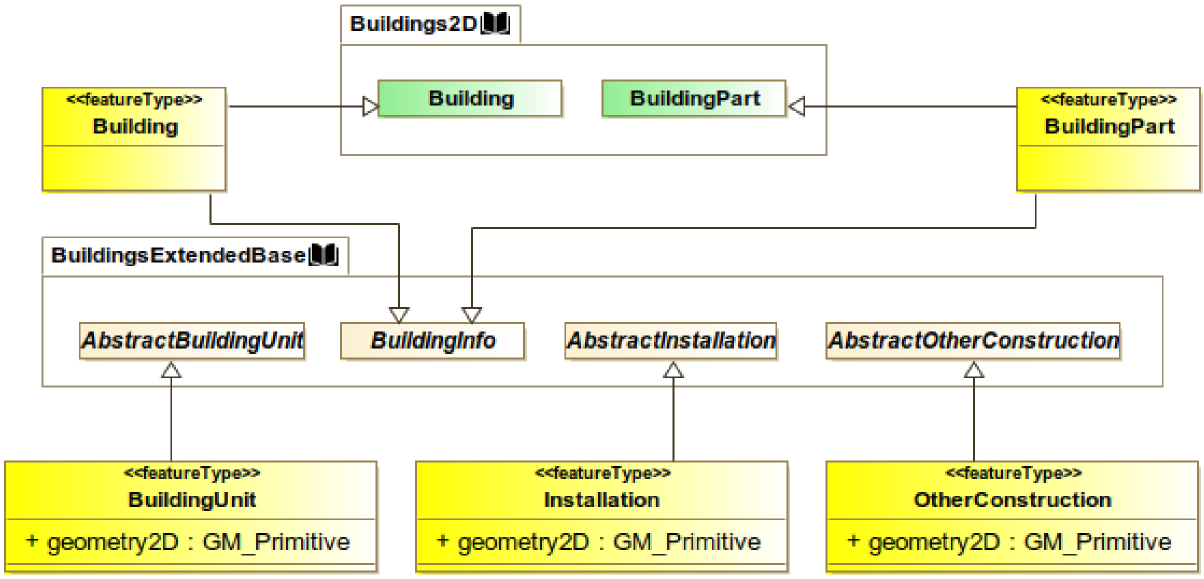


Figure 3.5: Buildings extended base 2D schema UML overview.

BuildingsExtended::BuildingInfo, including the attributes from ***BuildingsExtended::BuildingAndBuildingUnitInfo***, thanks to the inheritance within Buildings extended base schema as seen in the Figure 3.2.

Abstract feature types ***BuildingsExtended2D::AbstractBuildingUnit***, ***BuildingsExtended2D::AbstractOtherConstruction*** and ***BuildingsExtended2D::AbstractInstallation*** have children adding `geometry2D` attribute with a geometric primitive data type defined and described in [23]. Newly defined feature types **BuildingUnit**, **OtherConstruction** and **Installation** inherits all semantic attributes from previously mentioned feature types adding geometry.

3.1.1.5 Buildings 3D application schema

For the understanding of the 3D objects geometry representation, it is important to know something about CityGML and its level of detail (LoD). CityGML is an extension of GML standardized by OGC as a language for representation of 3D city models and buildings. CityGML distinguishes five levels of detail, shown in the picture 3.6:

0 – basic 2D geometry,

1 – block model, footprint of a building with constant height,

2 – floor plan with a roof shape,

3 – model with accurate shape including doors, windows, chimneys etc.,

4 – accurate model including interior.

Figure 3.6: Levels of detail in CityGML, picture from [2].

In the Buildings 3D schema (shown in the Figure 3.7), both specific feature types **Building** and **BuildingPart** inheriting from ***BuildingsBase::Building*** and ***BuildingsBase::BuildingPart*** include only geometry attributes. For both feature types, all the attributes are the same:

- `geometry3DLoD1` – geometric representation of building or building part at the level of detail 1, using **BuildingGeometryLoD1** data type,
- `geometry3DLoD2` – geometric representation of building or building part at the level of detail 2, using **BuildingGeometryLoD2** data type,
- `geometry3DLoD3` – geometric representation of building or building part at the level of detail 3, using **BuildingGeometryLoD** data type,
- `geometry3DLoD4` – geometric representation of building or building part at the level of detail 4, using **BuildingGeometryLoD** data type,
- `geometry2D` – an optional attribute with 2D geometry, using **BuildingsBase::BuildingGeometry2D** data type.

Attributes **BuildingGeometryLoD1**, **BuildingGeometryLoD2** and **BuildingGeometryLoD** are also defined within schema Buildings 3D and use geometry multi–surface and geometry solid to represent buildings or building parts geometry. Feature types **BuildingGeometryLoD1** and **BuildingGeometryLoD2** are children of **BuildingGeometryLoD**. All data types provides information about geometry representation of a building in 3D in a given level of detail including estimated accuracy of a model.

Moreover, for building parts, at least one of **geometry3DLoD1**, **geometry3DLoD2**, **geometry3DLoD3** or **geometry3DLoD4** attributes must be provided. Buildings without building parts must have provided at least one of **geometry3DLoD1**, **geometry3DLoD2**, **geometry3DLoD3** or **geometry3DLoD4** attributes.

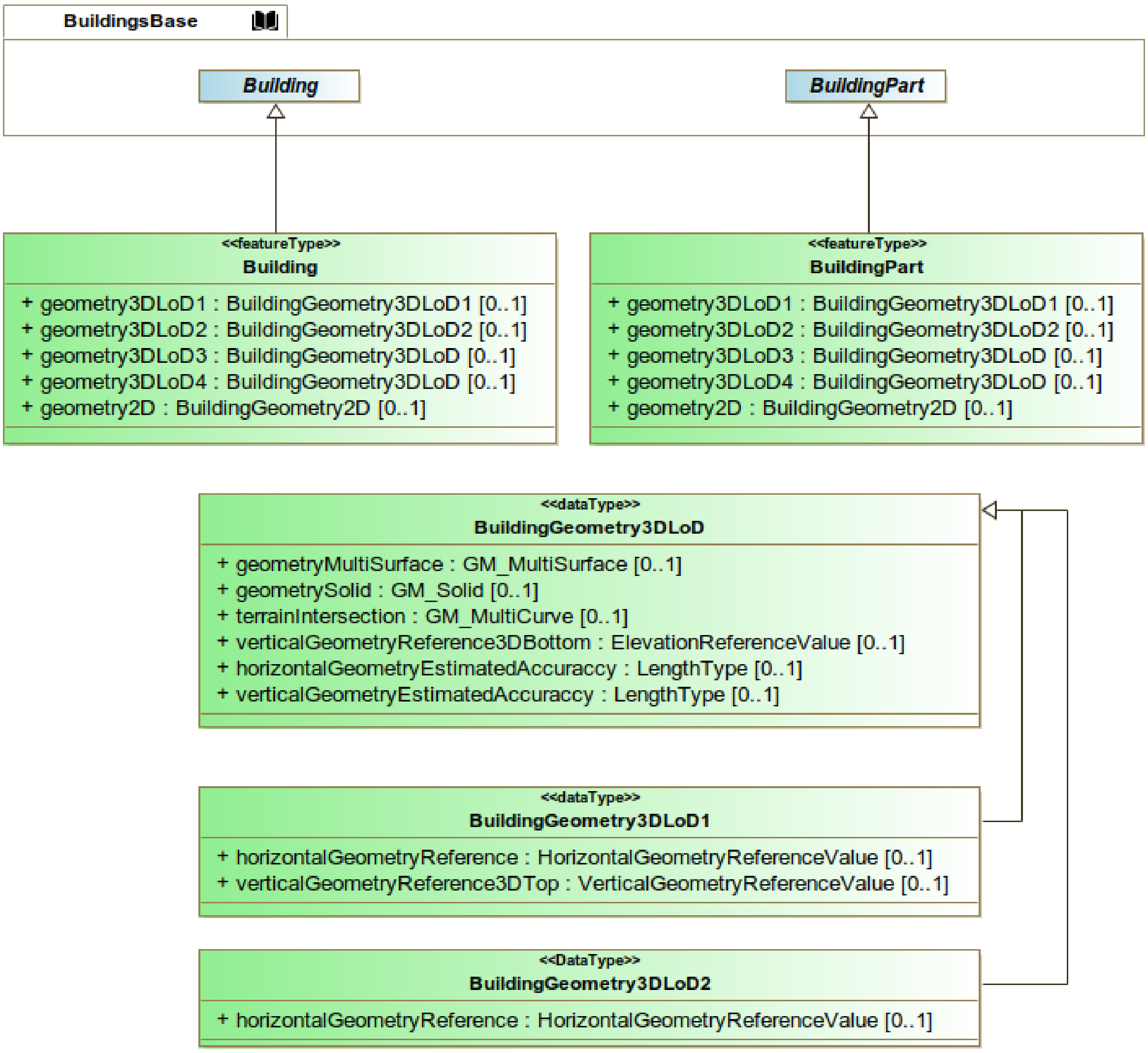


Figure 3.7: Buildings (Core) 3D schema UML overview.

3.1.1.6 Buildings extended 3D application schema

Basic feature types of Buildings extended 3D schema (shown in the Figure 3.8) is extension of both buildings 3D schema and buildings extended base schema. In this manner, it is quite alike the buildings extended 2D schema. **Building** and **BuildingPart** are children of **Buildings3D::Building** and **Buildings3D::BuildingPart**, inheriting base semantics and 3D geometry. Extended semantics are inherited from ***BuildingsExtendedBase::-BuildingInfo***. Here again, the multiple inheritance problem is encountered.

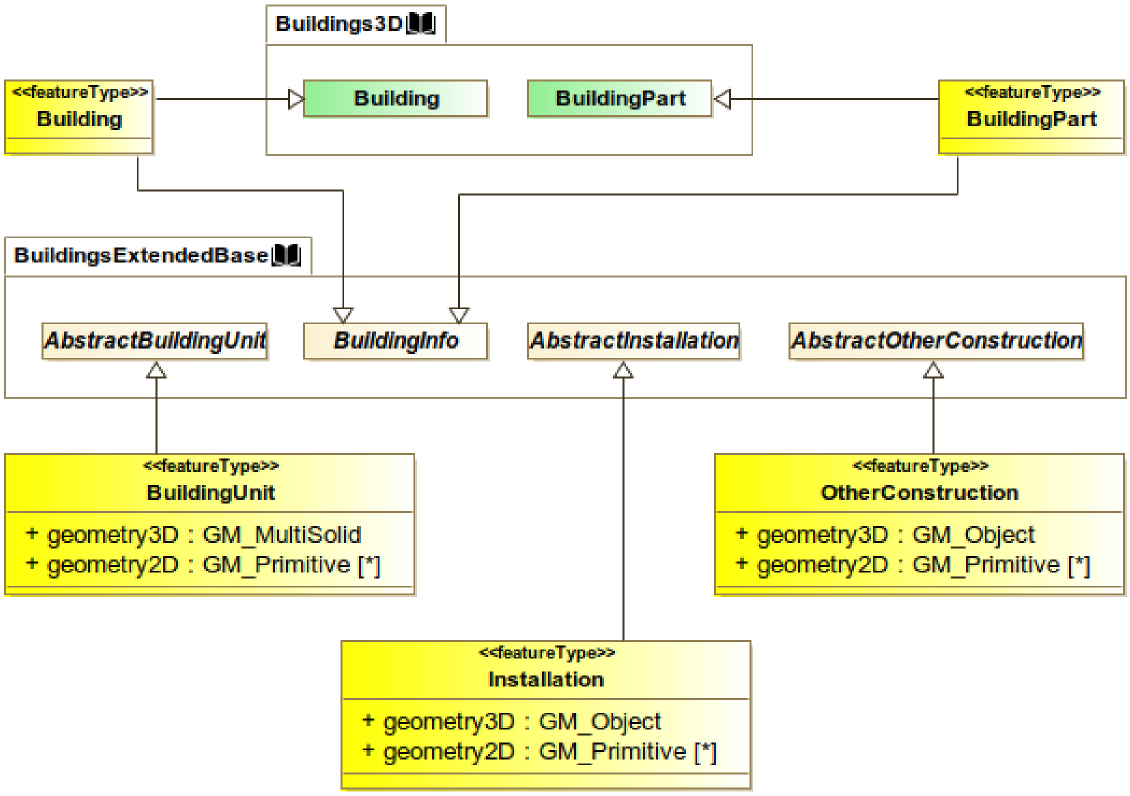


Figure 3.8: Basic feature types of Buildings extended base 3D schema UML overview.

BuildingUnit, **Installation** and **OtherConstruction** have a `geometry3D` attribute and optional `geometry2D` attribute to express geometry.

Based on the level of detail, special feature types representing components of the building are used. In LoD2 appear boundary surfaces such as walls or roof and installations attached to the outer boundary of a building. LoD3 adds openings (doors and windows) in the building boundary and LoD3 adds interior, such as building units, indoor openings, internal installations etc. Altogether it adds feature types

- **BoundarySurface** – with its specializations **RoofSurface**, **WallSurface**, **OuterFloorSurface**, **GroundSurface**, **OuterCeilingSurface** and **ClosureSurface**,
- **Opening** – with specializations **Door** and **Window**,
- **Room** and
- **InteriorInstallation**.

To express appearance of the material serves feature type **ParametrizedTexture** attached to the main features of the Building model.

3.1.2 Cadastral Parcels Data Specification document analysis

In comparison with Buildings, Cadastral Parcels have rather simpler model, containing only one application schema – Cadastral parcels. According to the Data Specification, the INSPIRE Directive focuses mostly on the geographical aspect of cadastral data and the data in Cadastral Parcels theme are meant to be used as locators for geo–information, including environmental data. It would be actually quite difficult to design the data structure in a detailed way to satisfy all member states[3]. In the end, all features contain geometry and brief information about national identifiers of cadastral objects. For even simpler data publishing, Data Specification on Cadastral Parcels mentions "Core" profile, containg only Cadastral Parcel with attributes and no constraints.

Due to the lack of multiple application schemas, all the information – both geometric and semantic – are stored at one place. "Core" profile is not taken into account in this dissertation thesis. In the UML schemas describing Cadastral Parcels, all feature types and data types are shown in beige.

3.1.2.1 Cadastral Parcels aplication schema

The overview UML schema is shown in the figure 3.9. It contains four feature types:

- **CadastralParcel** – is an area defined by cadastral register or its equivalent,
- **CadastralBoundary** – is part of a line between two parcels, or between parcel and another country,
- **CadastralZoning** – is an area of a national territory in which parcels are delimited,
- **BasicPropertyUnit** – is a basic unit of ownership recorded in the land books, registers etc. It basically covers ownership rights in areas in states, where basic cadastral units are not given to parcels.

The whole area of a country shall be divided into cadastral zonings and every place within cadastral zoning shall belong to exactly one parcel. In the context of INSPIRE, linking other objects to cadastral zonings or parcels allows users to find owners of the land as well as special circumstances assigned to the land (such as easements). Land registration has long history in all member states and each state is storing slightly different data according

[3]The situation is quite similar to the theme Addresses, where authors took into account (actually very good) all of the common features and attributes for all member states and described perfect model in less than 50 pages (in the original text). It is described in more detailed in my masters thesis [5], unfortunately only in Czech.

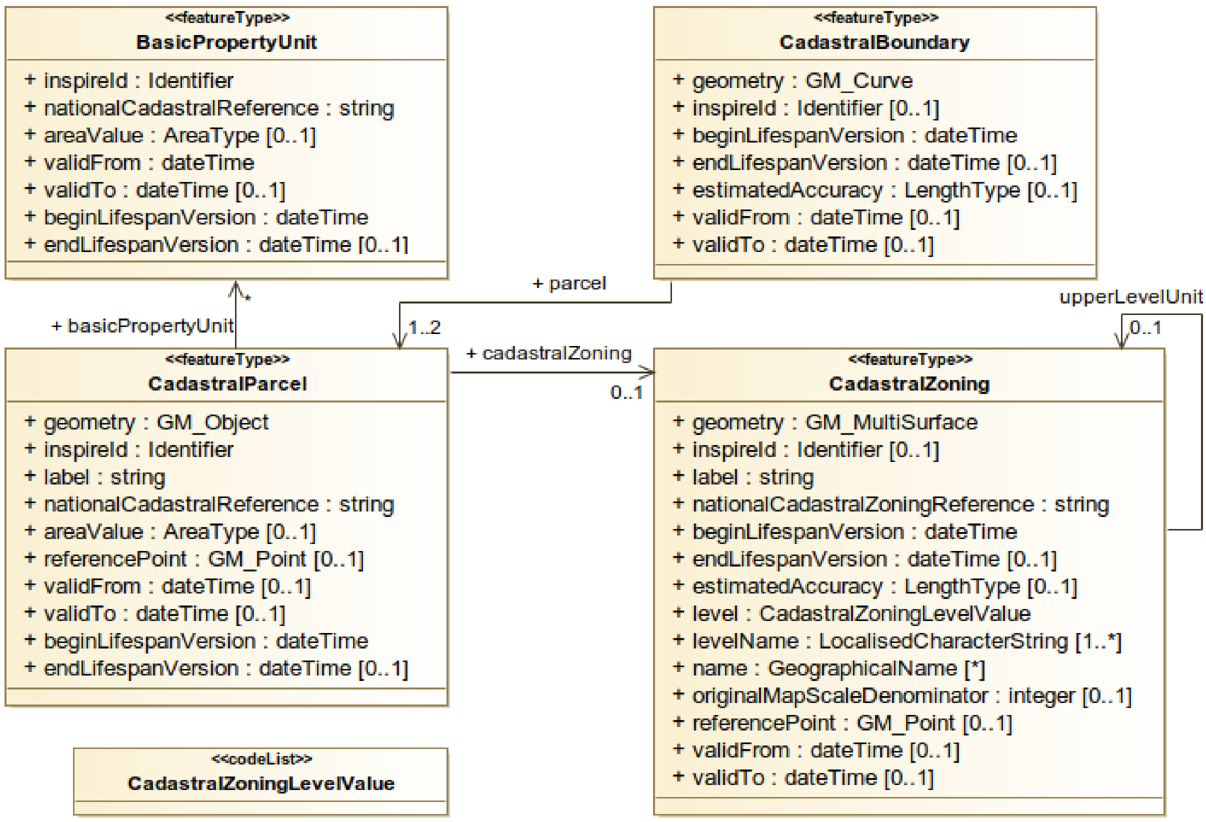


Figure 3.9: Cadastral Parcels schema UML overview.

to the national laws. In some countries, ownership is considered a private information and in other countries is even the cadastral number confidential. INSPIRE is not trying to solve this problem. Cadastral parcels contain reference to national cadastre in which is possible to find more information.

Feature type **CadastralParcel** is the "Core" feature type of the theme – implementation of only this one feature type is enough to fulfill INSPIRE requirements. It aims to fulfill the general usecase of Cadastral Parcels – locators of geo–information. Cadastral Parcels shall be forming the whole area of member state territory as much as possible. Parcel is a piece of land or water with homogenous property rights and unique ownership according to the national law. It contains following attributes (besides identifier and life cycle info):

- `geometry` – is a geometry representation of a parcel as a polygon or multipolygon,
- `nationalCadastralReference` – contains identifier of a parcel to the national level, usually within national cadastral registry, or better link to the parcel in that registry,

- areaValue – official area of a parcel (projected on the horizontal plane) in square meters,
- portrayal attributes referencePoint and label – containing what label a parcel has and were in the map is it displayed.

Cadastral Parcel is linked to **AdministrativeUnits::AdministrativeUnit** from the theme Administrative Units, **BasicPropertyUnit** and **CadastralZoning** from Cadastral Parcels. We will see in the further text, that this model of cadastral parcel is very brief and it is not much useful for national users.

Feature types **CadastralBoundary**, **CadastralZoning** and **BasicPropertyUnit** are auxiliary features. Auxiliary features are meant to be helpful for users and it is not obligatory by the member states to provide those data.

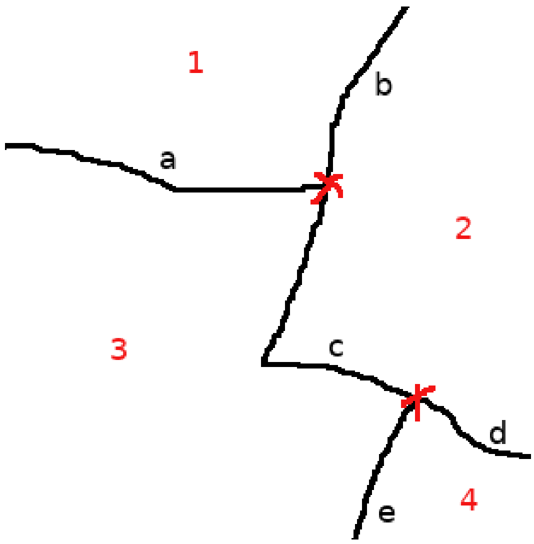


Figure 3.10: Cadastral boundaries are lines sharing same two neighbouring parcels. Cadastral boundary c creates border between parcels 2 and 3. But only the part of boundary between those two parcels. Border between parcels 2 and 1 have separate boundary b, respectively 2 and 4 have separeate boundary d. Red crosses represents the meeting points of three (or potentially more) cadastral parcels.

Feature type **CadastralBoundary** represents an outline of cadastral parcel. One boundary element is a line creating a border between two cadastral parcels (or part of national border neighbouring one cadastral parcel), as shown in the figure 3.10. Cadastral boundaries geometry has to form closed ring(s). Besides identifier and life cycle info, cadastral boundary contains attributes:

- `geometry` – 2-dimensional line geometry,
- `estimatedAccuracy` – absolute positional accuracy of the cadastral boundary given in meters.

There is also association role linking **CadastralBoundary** to one or two **CadastralParcel** features. Estimation of accuracy is related to the measuring method.

Intermediate areas used to divide territory into cadastral parcels are represented by feature type **CadastralZoning**. Zonings may also have administrative function for cadastral parcels, usually have been defined altogether with cadastral parcels for the first time. Ordinarily, **CadastralZoning** represents municipality, section, block or similar. It has sigificantly more attributes than parcels and boundaries, because of its ambiguity accross member states:

- `geometry` – 2-dimensional geometry of area, usually polygon or multipolygon,
- `nationalCadastralZoningReference` – contains full national code of the cadastral zoning,
- `name` – if any, contains a name of cadastral zoning,
- `level` and `levelName` in the national cadastral hierarchy,
- portrayal attributes `referencePoint` and **label** – containing what label a zoning has and were in the map is it displayed,
- metadata attributes `originalMapScaleDenominator` and **estimatedAccuracy** – refers to denominator of the original paper map to whose extent the zoning corresponds and absolute positional accuracy of parcels within the zoning in used coordinate reference system in meters.

In the given enumeration are not listed identifier and life cycle info attributes. **CadastralZoning** feature type may refer to other **CadastralZoning** feature on the higher level of hierarchy by association role `upperLevelUnit`. The lower level zonings shall be parts of upper level zonings. Cadastral parcels shall belong to the lowest level cadastral zonings and every parcel shall belong to only one zoning on this level.

Some countries have a basic unit in cadastral registers or eqivalent that is not exactly a parcel. E.g. Finland has basic property units, that may be composed from 0 to many parcels, or in Norway, parcels may belong to more than one basic property unit[4]. Those units are represented by feature type **BasicPropertyUnit**. According to the recommendation 41 in Data Specification on Cadastral Parcels, basic property units should be published only

[4]both examples are mentiond e.g. in the documentation of `BasicPropertyUnit` element in the XSD for Cadastral Parcels available at `https://inspire.ec.europa.eu/schemas/cp/4.0/CadastralParcels.xsd`.

when cadastral references are not given to parcels. **BasicPropertyUnit** does not have a geometry attribute. Besides identifier and life cycle info, it contains following attributes:

- `nationalCadastralReference` – is a full national code of a basic property unit, typically ensuring link to national cadastral register,
- `areaValue` – contains registered area value projected on a horizontal plane given in square meters.

Association roles may link **BasicPropertyUnit** to **AdministrativeUnits::AdministrativeUnit** feature from the theme Administrative Units.

Compared to previously shown theme Buildings, theme Cadastral Parcels seems much simpler in terms of complexity and richness of a model. The reason is that INSPIRE expects parcels to be used as locators for othe geo–information, basically for environmental data. National cadastral agencies provides usually much more complex and rich information about their cadastre, but those information differs too much state to state and are not crucial for the application in INSPIRE.

3.2 Technical realization of application schemas

Models described in Section 3.1 are conceptual models of application schemas. Besides textual description and model visualisation, models have to be expressed using technical programming or modelling language. On the INSPIRE web pages operated by JRC are published XML Schema Definition (XSD) schemas for most INSPIRE themes. XSD is a schema language for XML and W3C recommendation from 2001. It is not the only one schema language for XML, but it is one of the most robust and the whole language is in XML itself. It supports inheritance, which is really important for INSPIRE model, as well as import of other application schemas. This is important mainly because of the use of GML – geographical extension for XML is also defined in a set of XSDs (more about GML and XSD for GML in [24]). In the context of INSPIRE it is also useful for allowing data types and feature types from one schema to be reused in another. E.g. buildings extended 2D and buildings extended 3D schemas would be very difficult to model without the possibility of using feature types from application schemas buildings base and buildings extended base.

On the other side, XSD have some restrictions, that have to be solved in order to model INSPIRE data in the full extent. First, XSD (or XML in general) does not allow multiple inheritance. There are ways how to go around this problem, but the model would not stay the same. The work arounds are descibed in the section 4.2.1. Other problem is how to express constraints. In XSD 1.1 there exist ways how to handle constraints, but it is quite complex with usage of XPath with absolute paths. Luckily there are other ways on how to check the compatibility of data according to the model. At the INSPIRE Geoportal there is access to the INSPIRE Reference validator[5] that serves for validation of data, services and metadata. For data validation it uses XSD validation (checks if the data are valid according to the model in the XSD) and it has also implemented software validation, where the software of validator checks the compatibilty. This way is used mainly for constraints and dependencies between values. Biggest benefits of XSD are its portability and extensibility.

XSD schemas (and GML data as an output) have a support from JRC (by preparing and publishing them on the official INSPIRE web), but they are not the only option. It is perfectly valid to publish the data in different format and still be INSPIRE compliant, if data structure is according to the model. This means presence of the given feature types with described attributes.

Schemas are to be downloaded at the https://inspire.ec.europa.eu/schemas/. Index at the web address includes all the versions that were published, including the first draft versions. Double check the version before using it for data validation.

Last two versions – 3.0 and 4.0 – are not related to different versions of Data Specification documents. For most administrative themes, both versions have only technical differences, but some topographical themes – e.g. Hydrography or Transportation Networks – have defined new feature types and/or attributes.

3.2.1 Basic technical description of XSD language as used in INSPIRE

To fully understand the process of modelling application schemas in XSD is advisible at least basic knowledge of XSD language. Design of XML schema uses few basic components:

- `element` – represent specific elements, usually with given type,
- `complex type` – represents type consisting of elements and/or attributes,
- `simple type` – represent type that have no attributes or child elements,
- `attribute` – represents attribute with simple type,
- `group` (of elements) – associates multiple elements in a group,
- `attribute group` – associates multiple attributes in a group.

Relations between components are realized using compositors and wildcards. Compositors are used to create content of complex types by other elements and attributes. Type of compositor define type of relation between elements. Wildcards are used to represent any element and are mostly used in abstract types. It is expected that they are defined by children types.

[5]It was originally planned to 15th May 2019 to make it official validator, but it was postponed with no clear public date of publication.

For reusing of elements from previously defined XSD schemas or schemas from the internet are used directives `import`, `include` and `redefine`.

All components, compositors, wildcards, directives and constraints are in detail described in the XML Schema Primer available at `https://www.w3.org/TR/xmlschema-0/`.

In the modelling of INSPIRE XML Schemas persists consensus of component usage for modelling. First, schemas describing base types and other relevant INSPIRE schemas are imported using `import` directive. All non–abstract features from modeled application schema are represented as `element` components. That ensures possibility of creating an element with a given name in an XML file using the schema.

Feature types itself are represented usually by complex types with base type **AbstractFeatureType** from GML schema. **AbstractFeatureTypes** ensures, besides other things, presence of geometry element. For extensions of existing application schemas, existing complex types from other XML schemas will be probably used as base type. Relations defining content of types – elements – are mostly `sequence` compositors. This type of compositors lists elements in the given order. Contained elements have defined cardinality, and sometimes nillability. Cardinality determines how many elements of the same name may occur in one instance of element with given type. Nillability is set to "true" or "false". If an element is nillable, it may occur in data without content corresponding to the schema. This is used in INSPIRE to express some (usually obligatory) elements as missing or unknown. In fact, INSPIRE provides a code list that defines reasons for missing a value using `nilReason` attribute of nillable elements, available at `inspire.ec.europa.eu/codelist/VoidReasonValue`. It contains three basic values and allows extensions:

- unknown – one particular value is unknown,
- unpopulated – value is not known/meassured for the whole data set,
- withheld – value may exist, but is confidential or not divulged by the provider.

Some of the elements described in previous paragraphs are shown in the example of XML Schema with a complex type element:

```
<complexType name="CadastralBoundaryType">
  <complexContent>
    <extension base="cp:CadastralBoundaryType">
      <sequence>
        <element name="boundaryType" nillable="true" type="gml:ReferenceType"/>
        <element name="originalGeometry" type="gml:ReferenceType"
                 nillable="true" minOccurs="0">
```

```
          <annotation>
              <documentation>-- Note -- contains original geometry with the
                  possibility of using arc segments</documentation>
          </annotation>
        </element>
        <element name="originalGeometryExists" type="boolean"/>
        <element minOccurs="0" name="originalGeometryType" nillable="true"
                  type="gml:ReferenceType"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
```

Example above is a complex type named `CadastralBoundaryType` extending `Cadastral-BoundaryType` from a schema with namespace `cp`[6], that stands for **CadastralParcels** XML Schema. It contains four elements in a sequence. Those elements must be in the order defined in the complex type. It is an extension – all elements and attributes defined in a base type are inherited too. Other type of relation is restriction, which redefines acceptable values for restricted elements.

Element `boundaryType` is nillable – if the value is not available, it may be left empty with a reason why is it so. Its type is `gml:ReferenceType`, which is defined in GML schema. Element `originalGeometry` have same type. There are some basic types defined in XML Schema itself. Most of other types are derived from them. Those types are:

- `string`,
- `decimal`,
- `integer`,
- `boolean`,
- `date`,
- `time`.

Element `originalGeometryExists` have basic type `boolean`. Elements `originalGeometry` and `originalGeometryType` have attribute `minOccurs="0"`. This means, that those elements does not have to occur in an instance of any element with this type. It is also possible to define maximum number of occurences by attribute `maxOccurs`. Default values of both of these attributes is ”1”. Without any further specification, element may occure exactly once.

[6]Namespace is a short for whole identifier (URI) of a schema imported into the document. In this case, it is defined in a part of schema not shown in the example.

Element `originalGeometry` have child element `annotation` with another child element `documentation`. Those elements serve to describe the model and to create documentation. Some programs (e.g. oXygen) can create documentation of XML Schema using content of those elements as description.

3.2.2 Buildings application schemas technical realization

Every application schema shall have standalone XSD schema, importing other schemas if needed. Current version available on the INSPIRE web is 4.0. For Buildings, version 4.0 is the same as version 3.0, both respecting Data Specification on Buildings in version 3.0 from 10th December 2012. Version 3.0 is also available on the web. It differs only in namespaces and imports.

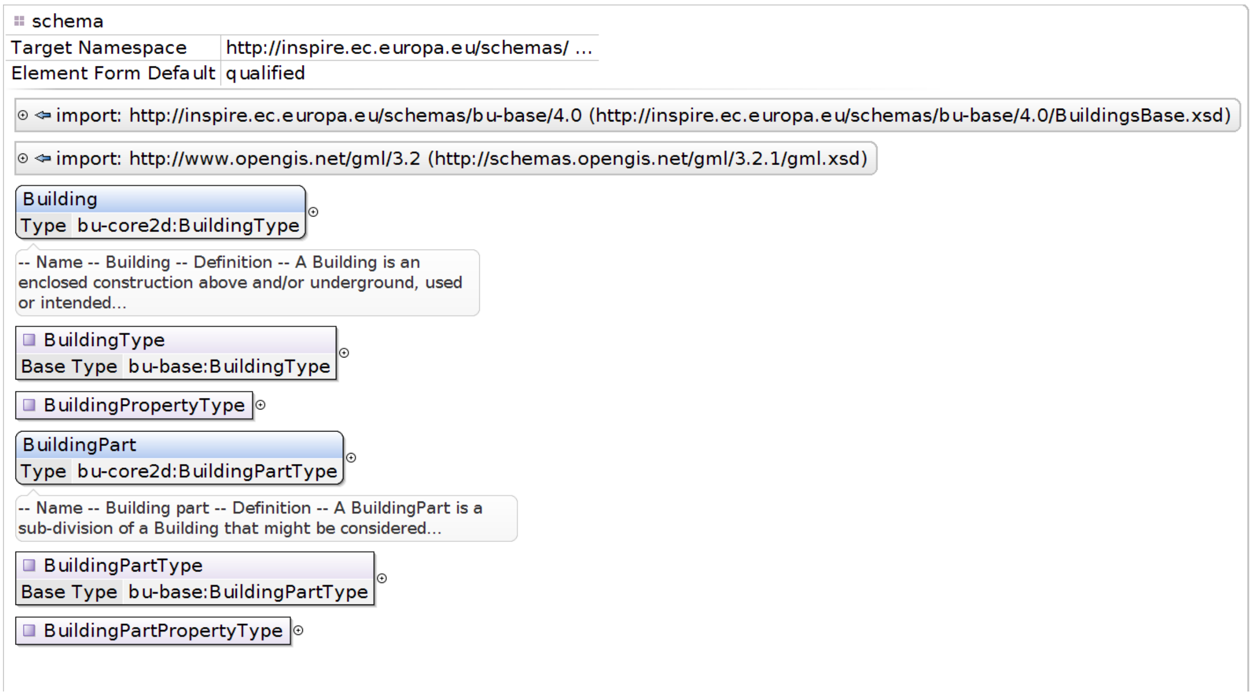


Figure 3.11: Overview of Buildings 2D XSD schema in oXygen software design view.

Following XSD schemas are available for Buildings:

- `bu--base` – XSD schema for Buildings base application schema, version 4.0 available at `https://inspire.ec.europa.eu/schemas/bu-base/4.0/BuildingsBase.xsd`,
- `bu--core2d` – XSD schema for Buildings 2D application schema, version 4.0 available at `https://inspire.ec.europa.eu/schemas/bu-core2d/4.0/BuildingsCore2D.xsd`,

◦ bu--core3d – XSD schema for Buildings 3D application schema, version 4.0 available at https://inspire.ec.europa.eu/schemas/bu-core3d/4.0/BuildingsCore3D.xsd.

In the Figure 3.11 is the overview of base elements of XSD schema bu--core2d. Schema contains two elements – Building and BuildingPart with defined types BuildingType and BuildingPartType. Both types are extensions of types defined in the bu--base XSD schema. The schema is imported using import component. The other import component imports GML – an XML schema containing geometry objects and types.

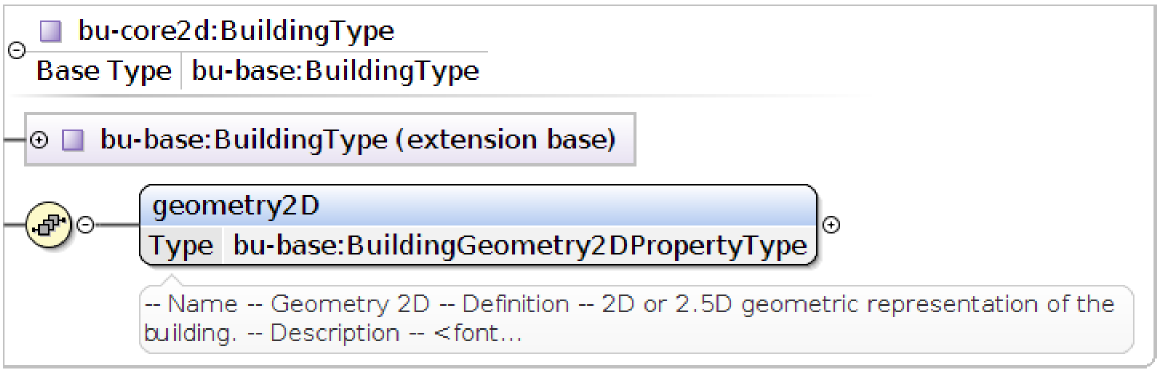


Figure 3.12: BuildingType definition from the Buildings 2D XSD schema in oXygen software design view.

Elements are object interpretations in the output data. The element Building defines the existence of Building elements in the data. It also defines its type and information that it is nillable or abstract. The type of the element is BuildingType. Type defines the structure and content of all elements with given type. Type BuildingType is shown in the Figure 3.12. Base type refers to the extension base – a type from which new type inherits all the properties. In this particular case, BuildingType inherits all elements and attributes (and technically all other properties) from type called bu-base:BuildingType. It is a type from bu--base XSD schema. Note that new type inherits also from all ascendants of its extension base.Type bu-base:BuildingType is an extension of bu-base:AbstractBuildingType, which is an extension of bu-base:AbstractConstructionType. Type BuildingType contains only one additional element – geometry2D. This element has its own type, cardinality and information about nillability. Note that it cannot be abstract once it is defined as an element of a type. Elements in abstract schemas are also abstract, but elements defined within types – even in the abstract schemas – are always specific.

As was written in 3.1.1.4, Buildings extended 2D and Buildings extended 3D application schemas encounter multiple inheritance problem. For theme Buildings, only base, core

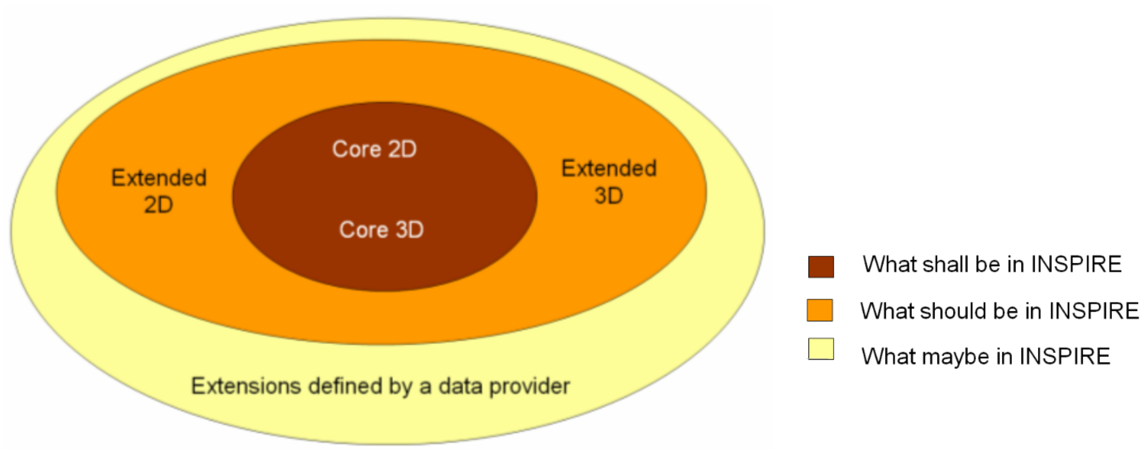


Figure 3.13: What application schemas shall, should or may be in the INSPIRE national implementation. Picture is from the Data Specification document on Buildings in version 3.0.

2D and core 3D schemas are modeled and published as XSD by JRC. According to the Data Specification document (specific fragment of it shown in the Figure 3.13), for the basic implementation, implementation of core schemas is enough to be fully compliant with INSPIRE requirements. For Buildings extended base, Buildings extended 2D and Buildings extended 3D are yet no offical XSDs available.

3.2.3 Cadastral Parcels application schemas technical realization

Cadastral Parcels theme have only one XSD schema corresponding to the application schema. Current version 4.0 differs from the older version (3.0) in version of imported schemas and in format of annotations. Structure and content remains the same as in the older version. Both versions of schema respects Data Specification on Cadastral Parcels in version 3.1 from 17th April 2014.

For the theme Cadastral Parcels is available XSD schema:

- `cp` – XSD schema for Cadastral Parcels application schema, version 4.0 available at: `https://inspire.ec.europa.eu/schemas/cp/4.0/CadastralParcels.xsd`.

For technical description of XSD language features please check previous section 3.2.2. In the Figure 3.14 is the overview of base elements of XSD schema `cp` describing Cadastral parcels application schema. It contains elements for each feature type and complex types describing the structure of elements. From other INSPIRE themes, `cp` imports and reuses schemas for themes Administrative units and Geographical names. Imports were cut from the picture for better readability.

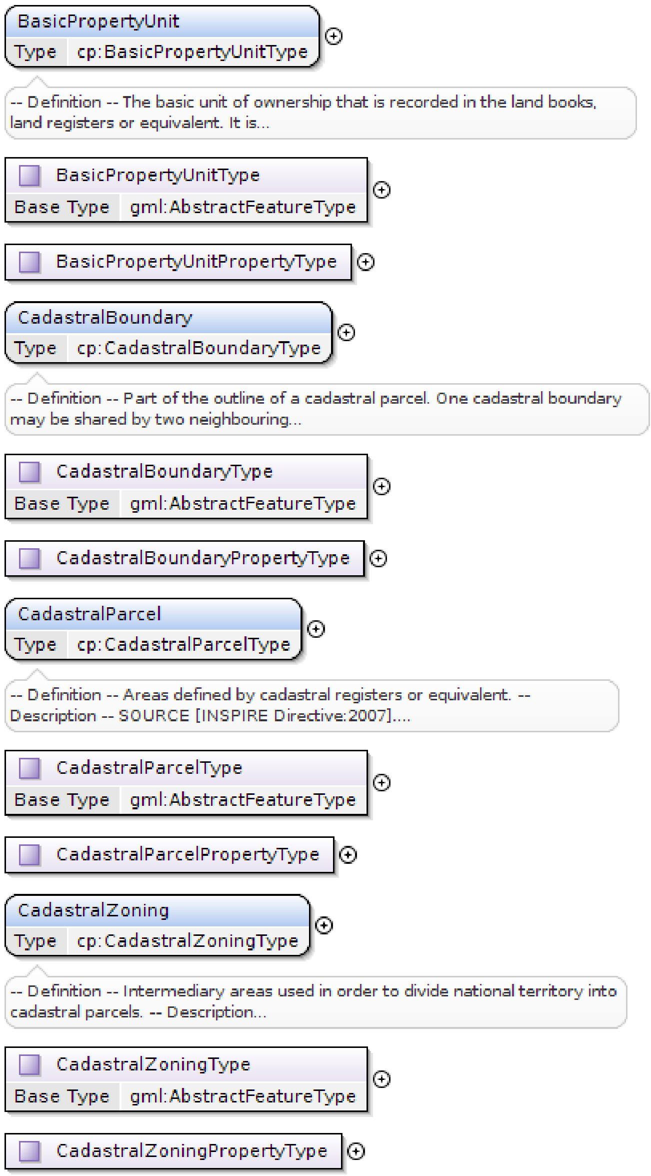


Figure 3.14: Overview of Cadastral parcels XSD schema in oXygen software design view.

Application schema Cadastral parcels is very simple and has no logical errors. The whole theme can be modeled using only one XSD schema, although it reuses some types from themes Administrative units and Geographical names.

3.3 National data sets analysis

Data described by INSPIRE Data Specifications are usually already published in member states in their national data sets. Every member state have its own legislation for individual (spatial) data sets, that may define structure and format of published data. Both structure and format may be very different from INSPIRE models.

In the Czech Republic, both Buildings and Cadastral parcels data are managed, maintained and published by the Czech Office for Surveying, Mapping and Cadastre. The office manages two main information systems – Information System of Cadastre of Real Estates (ISKN) and Information System of Territorial Identification (ISÚI). Both systems are used as agenda editation systems for Register of Territorial Identification and Real Estates (RÚIAN), which is main reference data source for addresses and territorial identification in the Czech Republic. RÚIAN is part of the Basic registers established by the Law no. 111/2009 Sb., about basic registers, that shall solve problems with ambiguity, multiplicity and obsolence of data in the public administration. ISÚI is also only source of Cadastral map and Cadastre of Real Estates as a whole. Cadastral data in the Czech Republic are published as various data sets by format, time and level of detail (country or cadastre units – czech equivalent of cadastral zonings). RÚIAN is published as data sets according to the content, coordinate reference system, level of detail (depending on content) and time.

The official format used for cadastral data is Cadastral exchange format (VFK) – proprietary format developed by external contractor of Czech Office for Surveying, Mapping and Cadastre. Likewise, RÚIAN exchange format (VFR) was also developed by external contractor, but it was designed as an extension of Geography Mark-up Language (GML) in version 3.2.1. Data are also available in other widely used formats – Shapefile, CSV, DGN or DXF. Some of the data are also available via web services.

All data of ISÚI and ISKN are stored in Oracle database with spatial extension Oracle Spatial. Due to INSPIRE implementation was created the publication database. This database manages data intended for publishing in a structure close to the structure of output data and it is updated regulary from the source databases ISÚI and ISKN. It usually contains only up–to–date data. Published data sets are generated from it and the services are using this, too.

3.3.1 Analysis of national data sources for INSPIRE theme Buildings

Data corresponding to the definition of building according to INSPIRE are present in both ISÚI and ISKN[7]. RÚIAN contains an object called "stavební objekt" – literally translated

[7]Both ISÚI and ISKN are agenda editation systems of RÚIAN, but not all informations from ISKN are part of RÚIAN.

as construction object (semantic meaning is equivalent to building) – defined in the §29 letter c) of the Law no. 111/2009 Sb. as:

- finished building written in the Cadastre of Real Estates,
- or building as a part of parcel or building right and data about it are written to the parcel or building right,
- or other finished construction, that is not written in Cadastre of Real Estates, but has assigned description house number or registration number.

In ISKN is an object called building defined in the Law no. 256/2013 Sb., about the Cadastre of Real Estates (Cadastral Law), in §2 letter l) as:

- construction above ground attached to the ground by solid foundation that is spatially concentrated and mostly enclosed from outside by peripheral wall and a roof structure.

Moreover, building is also defined in the §3 article 1 letter a) of the Law no. 151/1997 Sb., about property valuation, as:

- construction spatially concentrated mostly enclosed from outside by peripheral wall and a roof structure with one or more bounded utility space.

Definition of a building according to the Law no. 151/1997 Sb. is used for building objects in a database ZABAGED® managed, maintained and published by the Land Survey Office.

Building according to INSPIRE Data Specification was defined in 3.1.1.1 as:

- enclosed construction above and/or underground, used or intended for the shelter of humans, animals or things for the production or economic goods.

Building according to INSPIRE refers to any structure permanently constructed or erected on its site. It does not have to be part of any register or have attached registration or descriptive number. This corresponds the most to the definition given by Law no. 151/1997 Sb., e.g. buildings stored in ZABAGED®. Anyway, there is no connection between buildings from ZABAGED® to the ISÚI or ISKN yet, though it is planned in the future.

Theme Buildings serves mainly for administrative purposes. The main sources for the INSPIRE Building objects in the Czech Republic are buildings according to the Basic registers and buildings according to the Cadastral Law. There is huge overlay between the sets of buildings and construction objects and their source databases are connected – it is possible to connect building to the corresponding construction object. However, there are some main problems to be faced:

- one ISKN building may be represented as few ISÚI buildings,
- the connection between ISKN building and ISÚI building is not direct and may be missing. It may rarely happen that the same object will be present in INSPIRE as two objects – once from ISÚI and once from ISKN – this is caused by known errors in ISÚI database, that are continually repaired,
- during the update of an object in either database is not possible to recognize if the INSPIRE object is the same object or new one and must have new ID attached. For connection of objects it is necessary to refer by the construction object or building by Cadastral Law identifier.

Building according to Cadastral Law and construction object according to Basic registers have different intended use and accordingly they have different attributes.

ISKN_BUILDINGS		
P *	ID	NUMBER (30)
	VERZE	NUMBER (30)
	STAV_DAT	NUMBER (2)
	DATUM_VZNIKU	DATE
	DATUM_ZANIKU	DATE
	RIZENI_ID_VZNIKU	NUMBER (30)
	RIZENI_ID:ZANIKU	NUMBER (30)
	CREATED_BY	VARCHAR2 (30 CHAR)
	CREATE_DATE	DATE
	UPDATED_BY	VARCHAR2 (30 CHAR)
	UPDATE_DATE	DATE
	TYPBUD_KOD	NUMBER (1)
	CAOBCE_KOD	NUMBER (6)
	CISLO_DOMOVNI	NUMBER (4)
	POPIS_BUDOVY	VARCHAR2 (1 CHAR)
	CENA_NEMOVITOSTI	NUMBER (14)
	ZPVYBU_KOD	NUMBER (4)
	TEL_ID	NUMBER (30)
	PAR_ID	NUMBER (30)
	PRARES_KOD_OWN	NUMBER (3)
	DOCASNA_STAVBA	VARCHAR2 (1 CHAR)
	JE_SOUCASTI	VARCHAR2 (1 CHAR)
	PS_ID	NUMBER (30)
	ISKN_BUILDINGS_PK (ID)	

Figure 3.15: Database table containing buildings from the database ISKN.

Main purpose of Cadastre of Real Estates is registration of parcels and buildings. Buildings in ISKN have very detailed geometry, usually both polygon and definition point. Depending on the way of measurement, the accuracy of geometry may vary, but it is usually in the tens of centimeters. To the other information about buildings in ISKN belongs link to the cadastral units (cadastral parcel and cadastral zoning), link to the upper level administrative or other units (municipality, part of municipality) and information whether the building is part of cadastral parcel and wheter the building is temporary. Building also bears the information about its type and use. All attributes of buildings including names are shown in the Figure 3.15. Identifier of a building is unique within Cadastre of Real Estates.

Purpose of building in Basic Registers is description of the object in an administrative way. Geometry representation of the object is just a point, but its semantic information is much richer. It contains information about built-up area, enclosed area and floor area, date of completion of an object and creation of the object in the database, number of flors and entrances, links to the upper level units (muinicipality, its part and municipal district), link to the cadastral parcel, presence of a lift and type of construction object and its use. Construction objects are also linked to the addresses. Identifiers are unique within ISÚI.

Every ISÚI building may have several entrances, although they are present as objects with attached technical–economical attributes. Those attributes are attached either to the construction object itself or to its functional parts – called entrances. Technical–economical attributes are:

- number of floors[8],
- number of flats,
- type of construction,
- connection to elecricity – yes or no,
- connection to sewerage and its type,
- connection to gas and its type,
- heating information including source and type.

Moreover, entrance contains link to its parent building and to a municipality, date of creation of the object in the database and unique identifier of an entrance. All attributes of construction objects and entrances in ISÚI are shown in the Figure 3.16.

[8] ISÚI does not distinghuish between floors above or underground. That is problem for mapping to INSPIRE building, because INSPIRE only distinguishes floors above and underground, but have no attribute containing total number of floors.

ISÚI_CONSTRUCTION_OBJECTS		
P *	KOD	NUMBER (9)
	NESPRAVNY	VARCHAR2 (3)
	IDENTIFIKACNI_PARCELA_ID	NUMBER (18)
	MOMC_KOD	NUMBER (6)
	COBCE_KOD	NUMBER (6)
	BUDOVA_ID	NUMBER (18)
	DOKONCENI	DATE
	JE_VYTAH_KOD	NUMBER (4)
	ZMENA_GRAFIKY	VARCHAR2 (3 CHAR)
	DRUH_KONSTRUKCE_KOD	NUMBER (4)
	ZMENA_DETAILU	VARCHAR2 (3 CHAR)
	OBESTAVENY_PROSTOR	NUMBER (8)
	POCET_BYTU	NUMBER (4)
	POCET_PODLAZI	NUMBER (4)
	PODLAHOVA_PLOCHA	NUMBER (6)
	PRIPOJ_EL_ENERGIE	VARCHAR2 (3 BYTE)
	PRIPOJ_KANAL_SIT_KOD	NUMBER (4)
	PRIPOJ_PLYN_KOD	NUMBER (4)
	PRIPOJ_VODOVOD_KOD	NUMBER (4)
	TYP_KOD	NUMBER (1)
	ZASTAVENA_PLOCHA	NUMBER (6)
	ZPUSOB_VYTAPENI_KOD	NUMBER (4)
	ZPUSOB_VYUZITI_KOD	NUMBER (4)
	PLATI_OD	DATE
	PLATI_DO	DATE
	ZRUSENY	VARCHAR2 (3 BYTE)
	NZ_ID_GLOBALNI	NUMBER (18)
	NZ_ID_ISUI	NUMBER (18)
	ZALOZIL_KDY	TIMESTAMP (3) WITH TIME ZONE
	ZALOZIL_KDO	VARCHAR2 (150 BYTE)
	ZMENIL_KDY	TIMESTAMP (3) WITH TIME ZONE
	ZMENIL_KDO	VARCHAR2 (150 BYTE)
	ODSTRANENI	DATE
	KATUZ_KOD	NUMBER (6)
	ISÚI_CONSTRUCTION_OBJECTS_PK (KOD)	

ISUI.UI_DETAILNI_TEA		
P *	KOD	NUMBER (8)
	STAVOBJ_KOD	NUMBER (9)
	NESPRAVNY	VARCHAR2 (3 BYTE)
	POCET_BYTU	NUMBER (3)
	POCET_PODLAZI	NUMBER (3)
	DRUH_KONSTRUKCE_KOD	NUMBER (4)
	PRIPOJ_KANAL_SIT_KOD	NUMBER (4)
	PRIPOJ_PLYN_KOD	NUMBER (4)
	PRIPOJ_VODOVOD_KOD	NUMBER (4)
	PRIPOJ_EL_ENERGIE	VARCHAR2 (3 BYTE)
	ZPUSOB_VYTAPENI_KOD	NUMBER (4)
	PLATI_OD	DATE
	PLATI_DO	DATE
	ZRUSENY	VARCHAR2 (2 BYTE)
	NZ_ID_GLOBALNI	NUMBER (18)
	NZ_ID_ISUI	NUMBER (18)
	ZALOZIL_KDY	TIMESTAMP (3) WITH TIME ZONE
	ZALOZIL_KDO	VARCHAR2 (150 BYTE)
	ZMENIL_KDY	TIMESTAMP (3) WITH TIME ZONE
	ZMENIL_KDO	VARCHAR2 (150 BYTE)
	ISUI.UI_DETAILNI_TEA_PK (KOD)	

Figure 3.16: Database tables containing construction objects and objects with attached technical–economical attributes in the database ISÚI.

RÚIAN buildings are accessible via web application "Veřejný dálkový přístup" (Public remote access), available at `http://vdp.cuzk.cz/vdp/`. Application uses web form to search for specific objects in RÚIAN, results are shown as a HTML page. The results have only informational character. Alternatively it is possible to download pre–defined files in RÚIAN exchange format or CSV. Output for a specific building in Public remote access is shown in the Figure 3.17.

Reference data are provided via eGon services of basic registers managed by the Management of Basic Registers, but those services are used only to communication between Basic Registers and registered Agenda Information Systems.

3.3.2 Analysis of national data sources for INSPIRE theme Cadastral parcels

Information about cadastral parcels in the Czech Republic are stored in the database ISKN managed by Czech Office for Surveying, Mapping and Cadastre. Theme Cadastral parcels

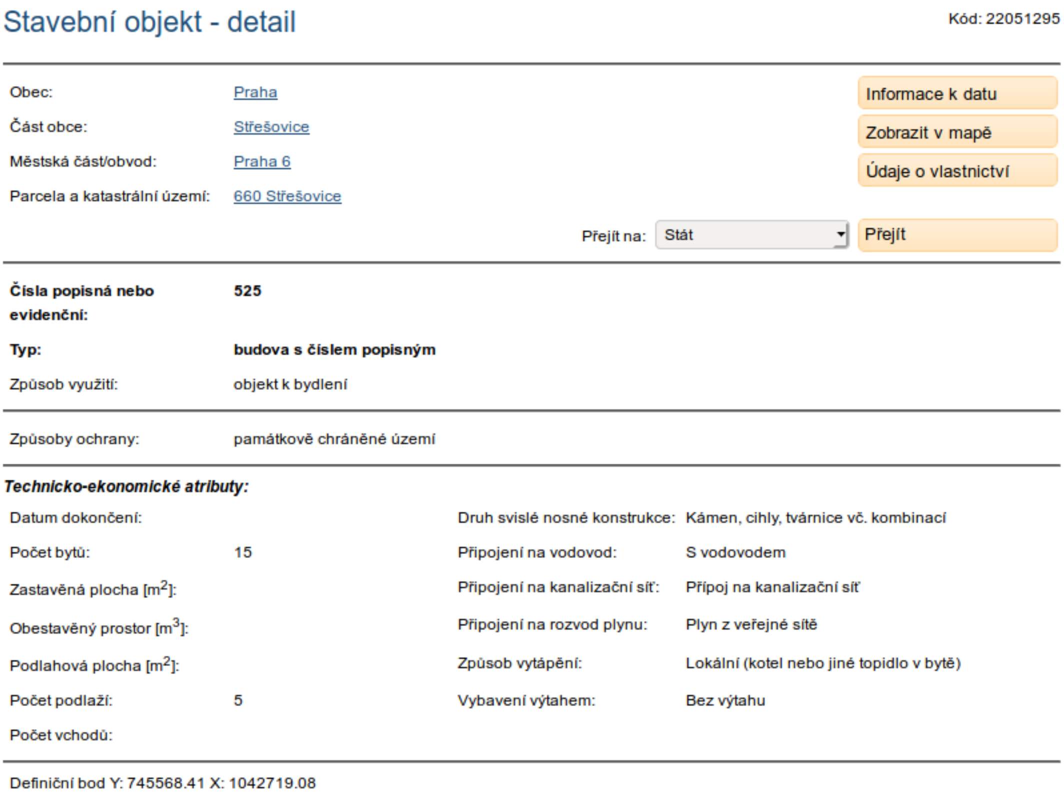


Figure 3.17: Construction object details in web application "Veřejný dálkový přístup".

contains four main feature types, but **BasicPropertyUnit** is not present in Czech data (it is equivalent to cadastral parcel). Data for other feature types – **CadastralParcel**, **CadastralBoundary** and **CadastralZoning** – are stored in standalone database tables.

Parcels store following information:

- area of a parcel,
- parcel number (it is a number of a parcel within cadasral zoning; it may include underline),
- link to cadastral zoning,
- link to building standing on a parcel (if any),
- index if parcel is construction or not,
- geometry – polygon, definition point and coordinates where is displayed parcel symbol, number and arrow in a map,

- link to cadastral boundaries of a parcel,
- area of a parcel,
- parcel type and use,
- date of cration of a parcel and date of creation of object in the database.

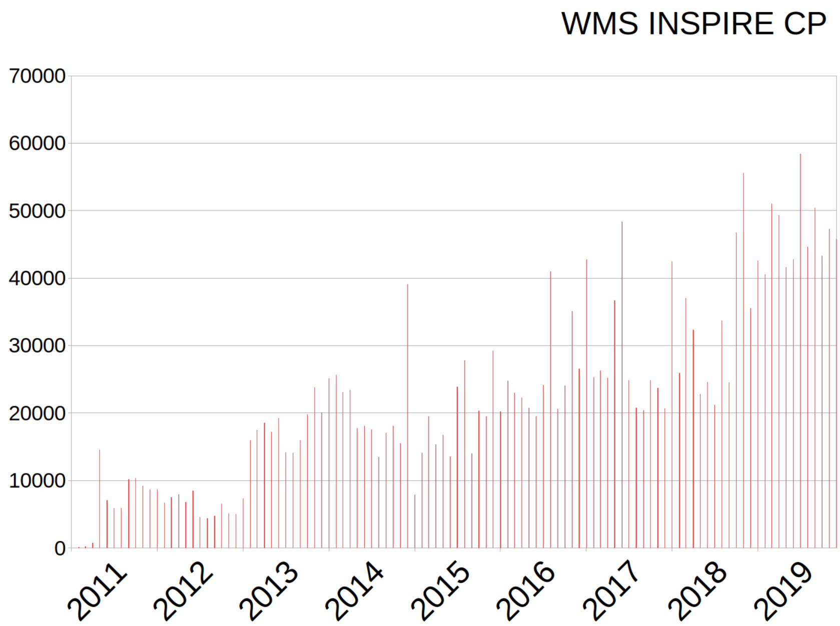
Parcels geometry is stored in various levels of detail. It is faster to render a map with lower precision data, but high accuracy data are available for large scale maps and calculations. Moreover, geometry may contain arc segments, not supported by most basic libraries on spatial data management. Therefore, the geometry is available in two versions – with arc segments or replaced by polylines. Notice that parcels contain much more information than it is needed by INSPIRE Data Specification on Parcels.

Boundaries are segments between exactly two parcels or between cadastral parcel and area of neighbour state. It contains links to both neighboring parcels, type of boundary (over 100 types based on administrative level of boundary, its visibility, importance, origin etc.), its geometry and estimated accuracy. Accuracy depends on a way of measurement and origin of object in a database. Naturally it contains also identifier and lifespan information about boundary and database object. Geometries are also in versions with arc segments and polylines.

Cadastral zonings, besides geometry and lifespan information, contains identifier and a name.

All three object types are basic parts of Cadastre of Real Estates in the Czech Republic. It is used for all types of administrative operations concerning properties, such as buying and selling parcels and buildings, land consolidation, ground and municipal plan administration, renting, settlement of inheritance and all kinds of proprietary relations. Cadastre have two parts – descriptive and graphic – where graphic part is publicly available. Descriptive part contains personal and confidential data. Content of database is controlled very carefully and contains much more information then it is required by INSPIRE Data Specification.

In 2012, Czech Office for Surveying, Mapping and Cadastre published new INSPIRE Cadastral parcels product. Data structure respects the structure given by application schema Cadastral parcels, all data are published as open data, accessible via Web Feature Service (WFS) as well as pre–defined GML files for cadastral zonings, freely downloadable from web pages. Data were also available as a view service using WMS 1.3.0. Unfortunately, data were not used by the national users. There are two WMS services providing cadastral data – INSPIRE WMS service for theme Cadastral parcels and WMS service for national Cadastral map. Both services are compliant to Technical Guidance for the implementation



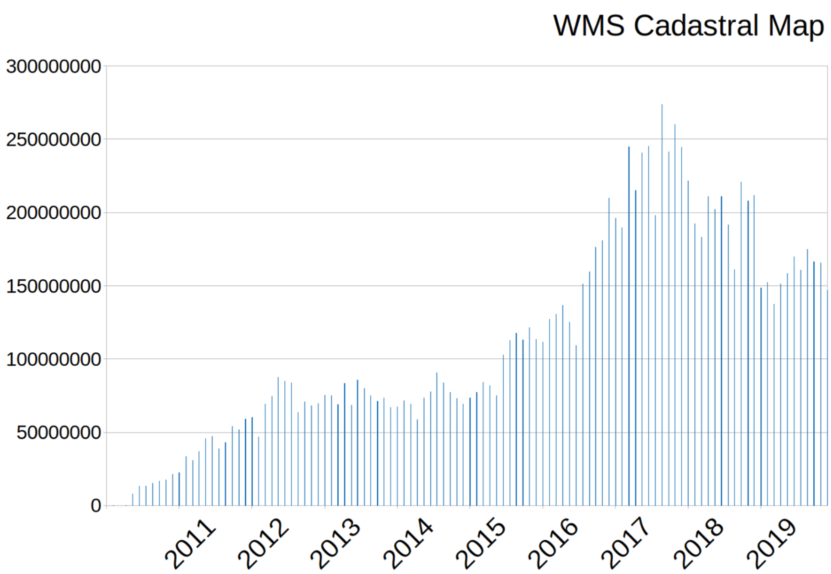


Figure 3.18: Comparison in number of accesses per month to the view service for INSPIRE Cadastral parcels (WMS CP) and Cadastral map (WMS KM).

of INSPIRE View Services, only the content of data differs. Cadastral map contains the full content of Cadastral map according to the Decree no. 357/2013 Sb., about the Cadastre of Real Estates (Cadastral Decree). Number of accesses to both services is seen in the Figure 3.18. The monthly peaks of INSPIRE Cadastral parcels are recently about 50 000 accesses, while Cadastral map have regularly between 150 and 200 millions of accesses per month.

This comparison shows that INSPIRE theme Cadastral parcels is not lucrative for Czech national users. For better understanding of the problem it is important to describe content of full Cadastral map according to the §3 of Decree no. 357/2013 Sb., about the Cadastre of Real Estates:

(2) Content of Cadastral map is planimetry and description drawn into map according to the rules given by the paragraph 10 of Annex to this Decree.

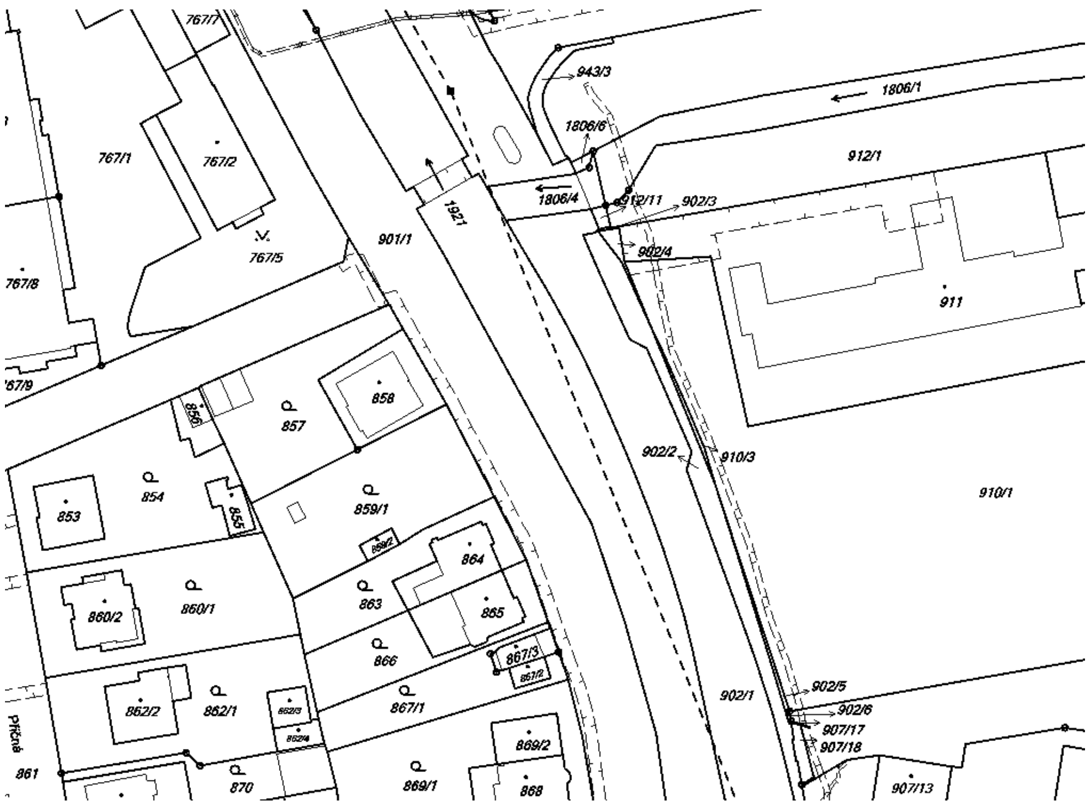


Figure 3.19: Image of Cadastral map according to the Cadastral Decree shows cadastral parcels, building perimeters including inner drawings, geodetic points, parcel numbers and symbols and easements.

Planimetry of the Cadastral map is describe in §5 of Cadastral Decree:

(1) *Planimetry of Cadastral map contains portrayal of boundaries of cadastral units, boundaries of administrative units, state boundaries, boundaries of parcels, building perimeters and water works registered in cadastre, other planimetry features, boundaries of protected zones and geodetic point fields. Digital form of Cadastral map contains portrayal of easment in the parcel parts.*

(2) *Other planimetry features are:*

   (a) *bridge,*

   (b) *culvert and tunnel in the embankment body of a road, if watercourse or rad goes through it (. . .),*

   (c) *perimeter of a building that is main building and is part of parcel or building right,*

   (d) *perimeter of a building that is secondary building and is part of parcel or building right.*

(...)

View service for Cadastral map vizualize the features listed above in appropriate way, example shown in the Figure 3.19. Cadastral map contains not only features not present in INSPIRE model, but also additional properties to the INSPIRE features, e.g. parcel symbols for cadastral parcels or types of boundaries for cadastral boundaries.

3.4 Analysis outputs

The target of analysis were data of only two INSPIRE themes and only over data sources of one office in only one European country, so it is not possible to come out with trends or general outputs. However, that was not a goal of the analysis. Goal was to focus on specific use cases on specific data and here it is possible to draw results.

Analysis of Data Specification documents and source data for the theme Buildings have shown that existing national data sets contain mostly data that are meant as a content of INSPIRE theme Buildings data sets. It does not make sense not to public data that are available and ready for publishing. Problem is not with the source data, but with the technical realization application schemas for Buildings. Data present in RÚIAN best fit to the application schema Buildings extended 2D. Technical realization for this application schema and for its parent abstract schema Buildings extended base does not exist. It is caused by technical problem with modelling multiple inheritance in XSD modelling language. This problem occurs in application schema Buildings extended 2D (and 3D) and is described in detail in Section 3.1.1.4. Its solution is crucial part of the implementation. Then it is important to create technical realization of application schemas Buildings extended base and Buildings extended 2D (as XSD schemas).

The intended source data for the theme Buildings in the Czech republic shall be data from following sources:

- ISKN – mainly for geometry,
- RÚIAN – for semantic information,
- ZABAGED® – to include buildings that are not in registers.

Unfortunately, ZABAGED® is not linked to other two systems.

Next step is to create transformation of source database data into INSPIRE structure. For this purpose shall be created new tables and views in the publication database. Tables shall store up to date data from the source databases and views allow direct access to the data as INSPIRE data sets (in a structure close to the one in which INSPIRE data sets are being published). It also has to be decided which information from the original data sets shall be published as part of INSPIRE.

Data shall be easily transformed into GML structure and published via standardized View and Download services. Application of the theme Buildings over national data shall bring more complex content available by standardized services. Current national data set – RÚIAN is in a well machine and human readable structure and format based on GML 3.2.1. The greatest opportunity for its improvement is in better access to the data in automated way.

Data in the structure given by the INSPIRE theme Cadastral parcels are already published in the Czech Republic since 2012. The biggest problem is a lack of additional information and objects besides those defined in the Data Specification on Cadastral parcels. On the other side, original data are published in a format that is really difficult to process – it is possible only with specialized software or modules. Data are not downloadable by any publicly accessible service (ATOM was created together with the application of INSPIRE), only in a form of pre-defined files (one file per cadastral unit) placed on the internet. This is a segment in which the publication of data according to INSPIRE rules – using GML format and publishing data via standardized Download service – brings huge enhancement. The extension of INSPIRE Cadastral parcels shall produce a data product providing the full content of Cadastral map with the biggest advantages of INSPIRE – open machine readable format and publication through standardized services.

To achieve this it is important to create a model of INSPIRE extension with new feature types and adding new attributes to the original ones. The model then must be realized as XSD schema.

Chapter **4**

Modeling, mapping and transformation

Next step to achieve the goal of this dissertation thesis is to create data models for the new INSPIRE data and create a mapping for transformation of data between source databases and INSPIRE data. Part of the modelling is creation of its technical realization in the form of XML Schemas. For the theme Buildings, XSD have to respect the model given by application schemas Buildings extended base and Buildings extended 2D. The extension of Parcels have no application schema or model so it must be created first.

Transformation is a process in which are data from the source database gradually put into the structure and format required by the INSPIRE Data specifications on specific themes. The transformation process is described in [25]. The general procedure of transformation process for INSPIRE themes in the environment of Czech Office for Surveying, Mapping and Cadastre, or basically any data transformation from SQL database into the GML files in a given structure, consists of several steps.

1. Data from the source database have to be moved (or copied) into the publication tables. Those tables contains only up to date data and only data intended to be published in the new data product. Those tables serve to update data regularly and to fasten the retransformation process by transforming only the data that appear in the final product. Tables usually follow the structure of the source database tables.

2. New products may consist from data stored in more databases or tables. In the publication database are created views grouping the data from various sources and creating the pattern for the objects of the final product. E.g. for building objects, information from various sources are put together in the view.

3. Data from database views are transformed into GML structure. This is usually done by some software. It is required to transform data on the fly. Download services usually requests part of the data set according to the value of some attributes, e.g. geometric position or area of the object. Transformation shall be possible for appropriate features only.

4. For better work with larger amounts of data are generated pre–defined files for larger areas, such as municipalities or cadastral zonings. Those files are generated only once in some time, e.g. daily, once per week or month.

The fundamental task for the transformation is to set suitable mapping from original data structure into the newly created model – in this particular case into the INSPIRE XSD structure. The vast majority of this task is solved in the transformation between publication database tables and views.

4.1 Design of a model for Cadastral Parcels extension

View service for Cadastral map is based on the Cadastral Decree – all the data have to be stored in the ISKN database. First it is needed to find possible feature types and then model the attributes and relations.

The goal of this part is to create INSPIRE model as an image of Cadastral map portrayal using existing INSPIRE data sets and their extensions. The first article of §5 of Cadastral Decree defines portrayal of the Castral map planimetry part.

(1) Planimetry of Cadastral map contains portrayal of boundaries of cadastral units, boundaries of administrative units, state boundaries, boundaries of parcels, building perimeters and water works registered in cadastre, other planimetry features, boundaries of protected zones and geodetic point fields. Digital form of Cadastral map contains portrayal of easment in the parcel parts.

Based on a fact that all administrative units in the Czech Republic including cadastral zonings are hierarchically compositional, cadastral boundaries can together form all levels of administrative units[1]. Information about administrative boundaries may be than stored as an attribute of **CadastralBoundary**. Portrayal of boundary according to its type is defined in a part 10.3 of Annex to the Cadastral Decree.

4.1.1 Cadastral parcels model feature types

Other planimetry features are described in the second article of the same §5 of Cadastral Decree. Anyway, all other planimetry features have a lot in common, thus they are put together in abstract feature type ***OtherFeature***. Types of other planimetry features are bridges, culverts, tunnels and buildings registered as part of a parcel or building right. According to the new Cadastral law no. 256/2013 Sb. is building part of the parcel. It is completely true for newly built buildings – they are written into cadastre as part of either

[1]According to the INSPIRE and Czech law, administrative units are municipalities, districts, higher territorial self-governing entity and country. Those units corresponds to the LAU2, LAU1, NUTS3 and NUTS1 levels.

parcel or building right. Quite a lot of the buildings already written into cadastre before 2013 already became parts of parcels but in many cases it was not possible. Those buildings are still registered as standalone objects, i.e. buildings listed in the first article of §5. All buildings in extended model of Cadastral Parcels are subclass of ***OtherFeature*** feature type, although Buildings is a standalone INSPIRE theme. Buildings in Cadastral map are present mainly for portrayal, but Buildings in Cadastral parcels extended model contain link to the Buildings theme features. Waterworks, such as dams, are stored as a type of building in cadastre. Note that not all buildings have polygon geometry in cadastre. Some buildings are not present in the file of descriptive information of a cadastre. Those buildings are also part of a Cadastral map, but with no descriptive attributes. It is important to distinguish between those two types of buildings. They are modeled as **Buildings** and **OtherBuildings** feature types in the new model.

Bridges, culverts and tunnels are put together as a **PlanimetrySupplement** feature type, together with other objects from the planimetry of Cadastral maps present in the ISKN database – mast, border mark, border mark on a state boundary (with different symbol), small object defined by centre point, small object without scale, lattice tower, symbol of watercourse narrower than 2 meters, standard gauge railway track axis, overhead line axis and high-voltage and power high-voltage lines.

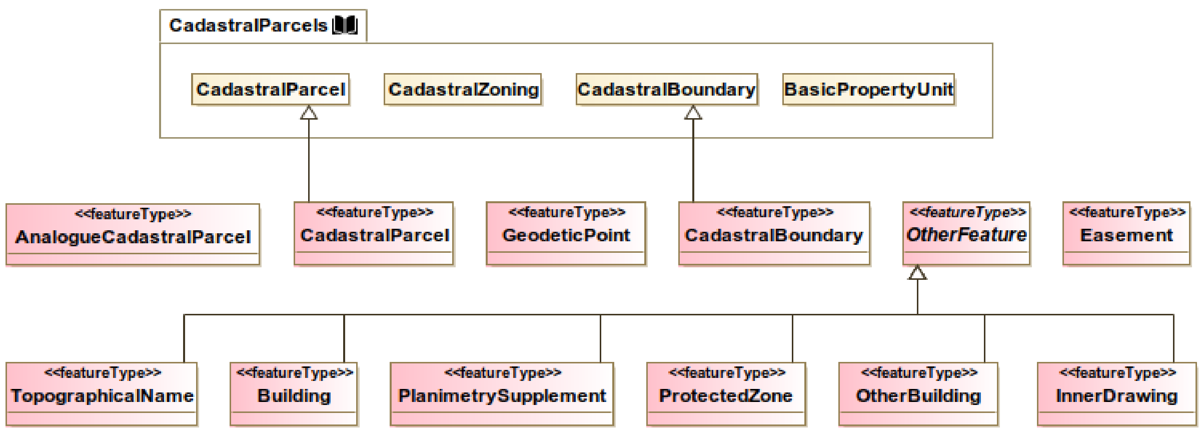


Figure 4.1: First design of national extension for Cadastral Parcels based on the content of Cadastral map.

For the model is advantegous to reuse feature types if possible. ***OtherFeature*** shall collect features with no important semantic attributes primarily intended for portrayal in a map. This includes inner drawings and protected zones. Both do not correspond to any object present in a model. Inner drawing portrays division of a building in a map. In the model, these objects are represented as feature types **InnerDrawing** and **ProtectedZone** – subclasses of ***OtherFeature***.

Another part of Cadastral map are topographical names. Topographical names is also standalone INSPIRE theme managed in the Czech Republic by the Land Survey Office. Possibility of linking features from various themes together is burdened with a similar problem as in the case of buildings from ZABAGED® – there is no link between identifiers from those databases. Office is working on this problem, but the current state is not usable enough for the countrywide usage. Topographical names as part of the ISKN database are modeled as **TopographicalName** feature type, which is also subclass of **OtherFeature**.

First article of §5 mentions two more feature types – geodetic point fields and easements in parcel parts. Cadastral map distinguishes three type of points based on the type of point field they belong to – fundamental horizontal control point, minor geodetic control point and associated witness point of horizontal control. All three types of points are associated in one feature type **GeodeticPoint**. Easements mentioned in a portrayal of Cadastral map includes only those in th parcel parts – that make sense, because easements bound to the whole parcel are not visible in the Cadastral map. Anyway, they are present in the database and shall be part of the data model for extension of Cadastral Parcels as **Easement** feature type.

In the Figure 4.1 is fundamental model of feature types and hyponym and hypernym relations between them as it is designed based on the content of previous paragraphs. In the diagram are used feature types from the application schema Cadastral Parcels (beige) and new feature types are portrayed in pink.

Model assumes additional attributes for **CadastralParcel** feature type, therefore it is already present in the model. During the work on extension of INSPIRE Cadastral Parcels was digitalization of the Cadastre of Real Estates still in process. Some parts of the area of the Czech Republic are still not digitized – there is some information about those parcels in ISKN, but generally, polygons are missing. Polygonal geometry is key attribute of **CadastralParcel** feature type, so these parcels have to be modeled as different type of object. For this purpose is designed feature type **AnalogueCadastralParcel**.

4.1.2 Persistent identifiers

Every feature type shall have specific set of attributes describing properties of object types based on the content of ISKN database. Basic attibutes for INSPIRE objects are INSPIRE identifier and life cycle information. Every object was created in a specific slice of time as well as it will probably be put out of the system once it does not exist anymore. And every object has to be clearly and unambiguously identified among others. In the best case is this done by a persistent identifier – an identifier that does not change during the life cycle of the object. In the INSPIRE model, identifiers typically consists from local identifier and namespace, version is optional. Local identifier is the identifier of an object within the given namespace, which usually refers to the data set or data product (series etc.). Czech implementation of INSPIRE does not include history. For that reason does not make sense to include end lifespan of a version, because every feature either is valid and then exist in the data set, or is not and then it is not part of a data set anymore.

From the already published INSPIRE data sets in the Czech Republic, identifier may look like this:

```
<base:Identifier>
  <base:localId>AD.22315829</base:localId>
  <base:namespace>CZ-00025712-CUZK_AD</base:namespace>
</base:Identifier>
```

Where CZ-00025712-CUZK_AD is a namespace – identifier of data set series for the theme Addresses. Identifier of the object – AD.22315829 is unique within this namespace. The similar form of identifier is also present in metadata and in web services for downloading pre-defined data sets. Anyway, based on the principles of semantic web it would be better to identify objects by one identifier (preferable an URI) that consists from both local identifier and namespace.

4.1.3 Modeling of Cadastral Parcels Extended application schema

Besides the information already present in the Cadastral Parcels application schema for the feature **CadastralParcel** there are few crucial attributes needed for national users. Without them included, INSPIRE Cadastral Parcels data will not be used on the national level (based on the statistic shown in the Figure 3.18).

- Link to a building – the Law no. 256/2013 Sb., about a Cadastre of Real Estates, defines a building as part of the parcel.
- Map symbols – to be able to recreate portrayal of Cadastrastral map, features need to contain symbols, arrows and texts (such as parcel numbers) together with a location where to portray them.
- Land type and land use – Cadastre contains information about land use and land types based on the Annex of Cadastral Decree. But INSPIRE uses Hierarchical Land Use Classification System (HILUCS) with values defined in code list (available at `http://inspire.ec.europa.eu/codelist/HILUCSValue/`) for both land use and land types. It is originally intended to be used in INSPIRE theme Land use, but in the Czech Cadastre, this information is part of the parcel.
- Original geometry – geometry of parcels (and other objects) in the Czech Cadastre of Real Estates contains also arc segments. Geometry in INSPIRE models contains

only lines, polylines and polygons with line borders. For the full compliance of the extended model with Cadastral map, those arc segments shall be included in the model.

Boundary types are modeled as attribute of boundaries. Original arc geometries of cadastral boundaries are modeled same as for parcels.

In the Figure 4.2 is the model extended feature types **CadastralParcel** and **CadastralBoundary** with attributes. The technical realization of a model is described in Section 4.2.2 and it differs slightly from the model, because attribute types for map symbols and original geometry in XSD had to be yet designed and created. Types for HILUCS values are part of models for Land use theme.

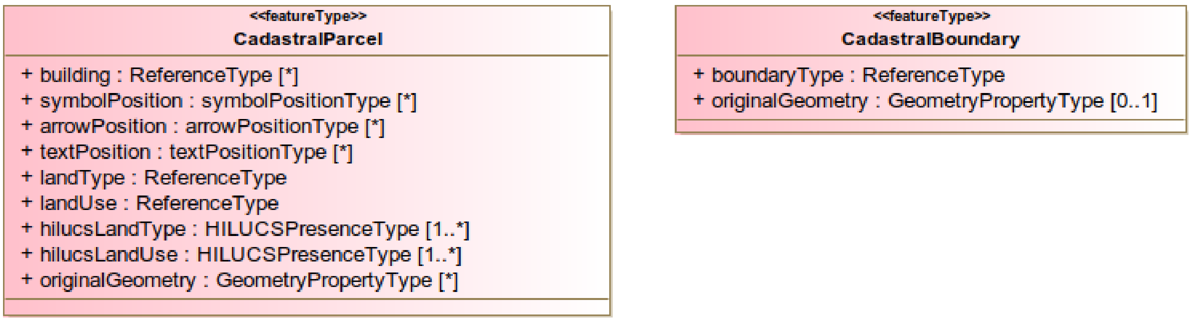


Figure 4.2: Model of extended feature types **CadastralParcel** and **CadastralBoundary** including attributes.

Data structure of analogue parcels – parcels not yet digitized – shall be similar to the structure of regular cadastral parcels with an exception of geometry and other properties used for portrayal of data in a map. Regular cadastral parcels have polygonal geometry while analogue parcels are defined only by definition point. Analogue cadastral parcel shall contain all other information held for parcels, except those for portrayal. **AnalogueCadastralParcel** contains also attributes about land use and land type including hilucs and links to buildings connected to the parcel. Basic model of **AnalogueCadastralParcel** feature type is in the Figure 4.3.

Other standalone feature type is **Easement**. It shall serve for modeling easements relating to both parcel parts and whole parcels. Some easements may relate to more parcels or their parts. Distinguishing of those two types of easements have sense only for portrayal of easement in the Cadastral map – only easements related to parcel parts are portrayed. For the needs of extended INSPIRE Cadastral Parcels model is possible to

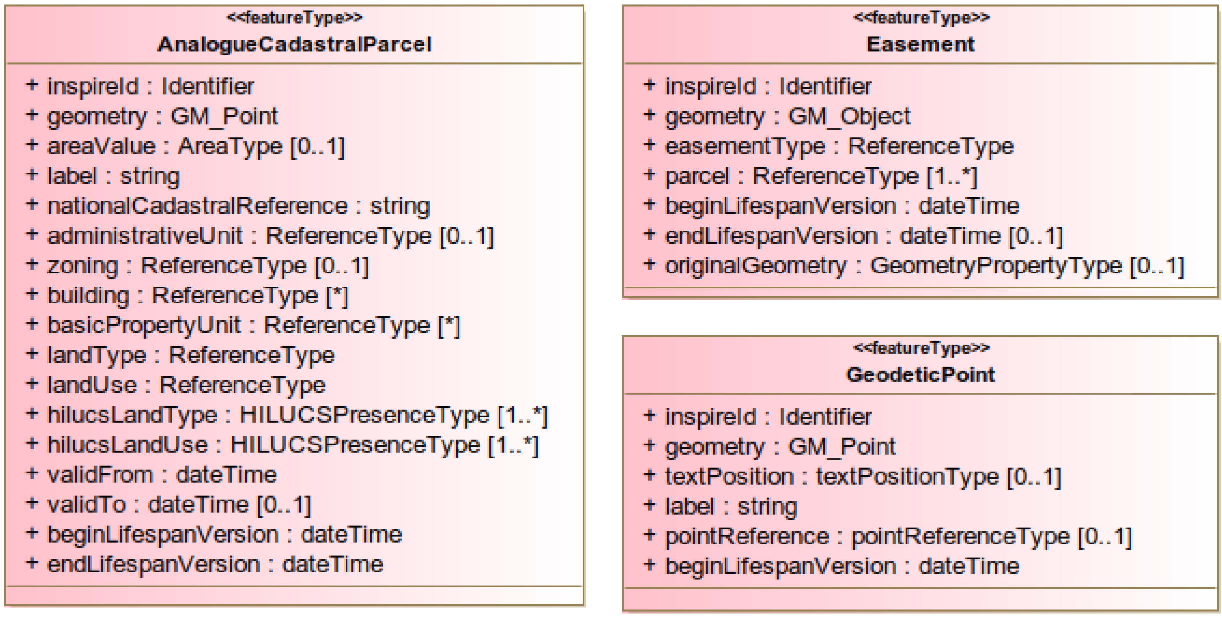


Figure 4.3: Model of new feature types **AnalogueCadastralParcel**, **Easement** and **GeodeticPoint** including attributes.

use one feature type. Information related to easements are defined in §16 article (1) of Cadastral Decree as:

a) *content of easement by its brief description,*

b) *information about the burdened parcel including information about* the geometric plan for easements related to parcel part,

c) *information about compulsory in case when easement relates only to co-ownership of real estate,*

d) *information about ruling parcel or authorized person,*

e) *last day of easements validity, if defined.*

Letters c) and d) relates to the non-public part of Cadastre, the rest will be modeled. Cadastre of Real Estates distinguishes multiple types of easements according to the Law no. 89/2012 Sb., the Civil Code. Model of **Easement** feature type is in Figure 4.3.

Czech Cadastre defines three basic types of geodetic point fields – horizontal geodetic control, vertical control and gravity geodetic control. Only horizontal geodetic controls are part of Cadastral map. Points in the point fields are divided into three categories –

fundamental, minor and associated. All three types have different identification number series, but they have same properties:

- position – position of a point,
- number – number of a point, numbered within cadastral zoning,
- text position – position where is it portrayed point number, including posible rotation and scale ratio,
- reference to cadastral zoning,
- point type and id – type of point and its id within the whole geodetic control field type.

Moreover, every point has unique inspire identifier and life cycle information. Model of **GeodeticPoint** feature type is in Figure 4.3.

All other feature types are children of abstract feature type ***OtherFeature***. It associates all features that does not represent any of main feature types and are intended to be portrayed in a map. Basically it contains planimetry supplements, protected zones, buildings, inner drawings and topographical names. Besides the fundamental INSPIRE attributes (identifier, life span information and geometry) they contain the information about cadastral zoning. Information about cadastral zoning to which every feature belong make it then much easier to get the context of the data. Some of other feature types may be further divided into suptypes. That type is expressed as attribute of other feature.

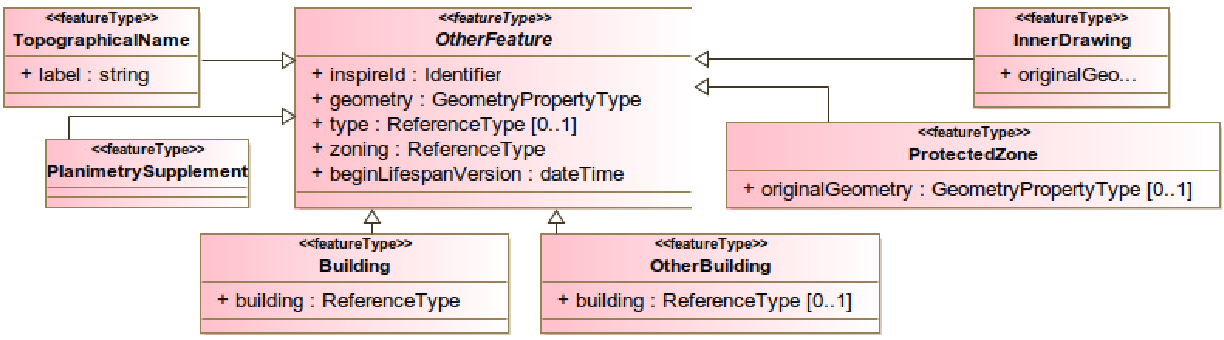


Figure 4.4: Model of new abstract feature type **OtherFeature** and its children including attributes.

Other features may be represented in a map either by its geometry (e.g. points, polygons, polylines or curves), as a text localised at a specific position or a map symbol. Type of geometry attribute depends on that. Buildigs, some protected zones (e.g. memorial trees) and some planimetry supplements (e.g. masts) are represented as map symbols. Inner drawings, most protected zones (e.g. national parks, conservation areas) and some planimetry supplements (e.g. power lines) are represented by plain geometry. Topographical names are represented as a text located in a map. This distribution is important for technical reapresentation of feature types, but it is mentioned already here, because feature types from same groups have similar additional attributes.

Feature types represented as a plain geometry may generally have original arc geometry segments. Topographical names – as only representative of text position representation – must have defined label to portray at a location. All feature types represented by map symbol need a definition of a symbol to portray. Model of all feature types that are subtypes of ***OtherFeature*** are in the Figure 4.4.

4.2 Creating XML Schemas based on the application schemas

Models of application schemas represents the formal representation of data. They describe the objects, their properties and relations between them. Data have to be published in a data format, that have defined rules. For the publication of INSPIRE data is mostly used GML 3.2.1 format, which is extension of XML. One of the biggest advantages is possibility of creating data models in XML Schema Definition (XSD) file. XSD defines the structure of ouput data. Moreover, it allows inheritance and reuse of schemas already created. European Commission have published XSDs for most INSPIRE application schemas, and also used them to model basic data types. Basic description of creating XSDs is described in Section 3.2.1.

As written in Section 3.2.2, XSD files for application schemas Buildings Extended Base, Buildings Extended 2D and Buildings Extended 3D were not published due to logical problem in implementation of a model into a technical realization. Anyway, application schemas are defined in a Data specification document including content and structure. For Cadastral Parcels extension was the whole application schema created for the needs of national users and therefore may be still changed according to the upcoming problems from the side of mapping source data into the data structure.

4.2.1 XML Schemas for extension of Buildings

Application schemas for Buildings extended base and Buildings extended 2D already exist, that makes the technical implementation easier (for Cadastral Parcels they had to be designed first). On the other side there is no variability in the model. Model of application schema Buildings extended base is shown in the Figures 3.2 (feature types) and 3.3 (data types), model of application schema Buildings extended 2D is shown in the Figure 3.5.

4.2.1.1 Multiple inheritance problem

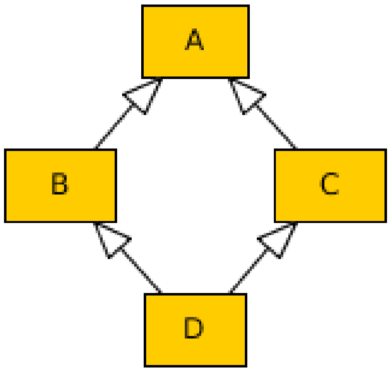


Figure 4.5: Diamond problem with ambiguous inheritance of attributes.

Technical realization of application schemas in a form of XSD files was not realized because of encountered logical problems in the realization of a model using GML[2]. It is already mentioned multiple inheritance problem – XSD does not allow one complex type to inherit from more than one type. Multiple inheritance problem occurs in application schema Buildings extended 2D for feature types **BuildingsExtended2D::Building** and **BuildingsExtended2D::BuildingPart**. Reason for modelling buildings this way is clear – geometry of objects shall be the same for all levels of semantic detail and likewise, semantic information shall be the same for all kinds of geometry representation. Anyway, in XML, one object is a bearer of attributes in given order. For the inheritance of objects, child inherits all attributes of parent in given order and allows extension or restriction of parent. Therefore it is ambiguous to inherit from two parents. Anyway, in a real world it is quite common to model situation requiring multiple inheritance (e.g. teacher is both human and employee of a school and inherits properties of both parent classes). Multiple inheritance problem may become diamond problem[3] – where classes B and C inherits from class A and class D inherits from both B and C (as seen in the Figure 4.5). If both classes B and C extends or restricts same attribute of A, inheritance of that attribute for class D is ambiguous.

There is several solutions for this problem in XSD, but none of them respects the model fully. It is caused by the very fundamental document of XSD – XML Schema 1.0 Spec

[2]Problem is not directly with GML, but generally in XML, whose extension GML is.

[3]Also called Deadly Diamond of Death problem.

– available from `https://www.w3.org/TR/xmlschema-1/`, defining that there can be only one extension element. Therefore it is not possible to inherit from more than one complex types. Anyway, there are some ways to work around the problem.

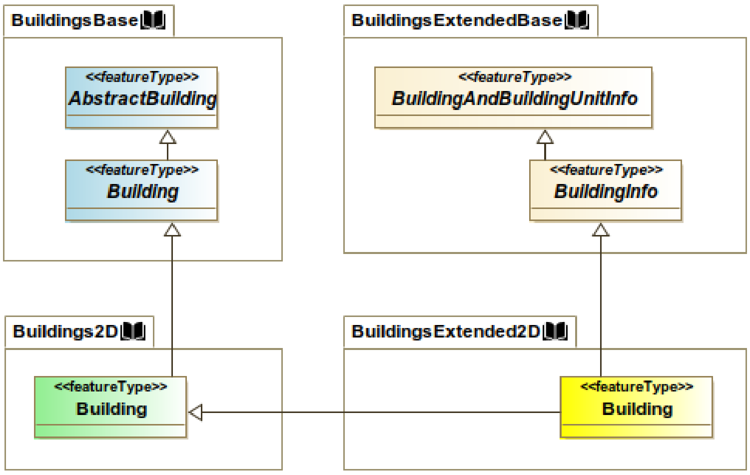


Figure 4.6: Model of inheritance relations in a theme Buildings for the **BuildingsExtended2D::Building**.

One of the possible solutions is to create named groups. `Group` is a component type used for putting elements together. Named group is a group with defined name, by which it can be referenced. Unlike types, groups cannot have attributes or base types. Work around the given problem with double inheritance of feature types **BuildingsExtended2D::Building** and **BuildingsExtended2D::BuildingPart** is creating groups of elements that could be included in the specific feature types instead of inheritance. Problem here is that the schema is too complicated and there is inheritance on multiple levels. In the Figure 4.6 is the element **BuildingsExtended2D::Building** in yellow. It inherits from both **BuildingsExtendedBase::BuildingInfo** and **Buildings2D::Building**, while each has at least one more parent. Work around the problem using groups is in creating group of elements for each level of inheritance and using it in another group for its descendants. This needs to recreate every complex type in the inheritance line. Sadly, XSDs for application schemas Buildings base and Buildings 2D already exist and it is not possible to easily edit them. It would be relatively complicated to work around the problem using groups.

In the Figure 4.7 is a design of part of realization of application schema Buildings base using the groups instead of inheritance. It has a lot of disadvantages, starting with reusing the same group all over. The biggest advantage of using XSD – the inheritance – is lost. Moreover, attributes or inheritance of types is not possible using groups (unlike complex types). The advantage is that all elements in the XML file valid against the XSD are on the same level, because group is only substitution of its elements. Generally, groups are intended to be used in definitions of complex types rather than substituting them. Note that complex types in the scenario in the Figure 4.7 are not descendants of upper level complex types as described in the application schema. Pros and cons taken into account, this is not a preferred solution.

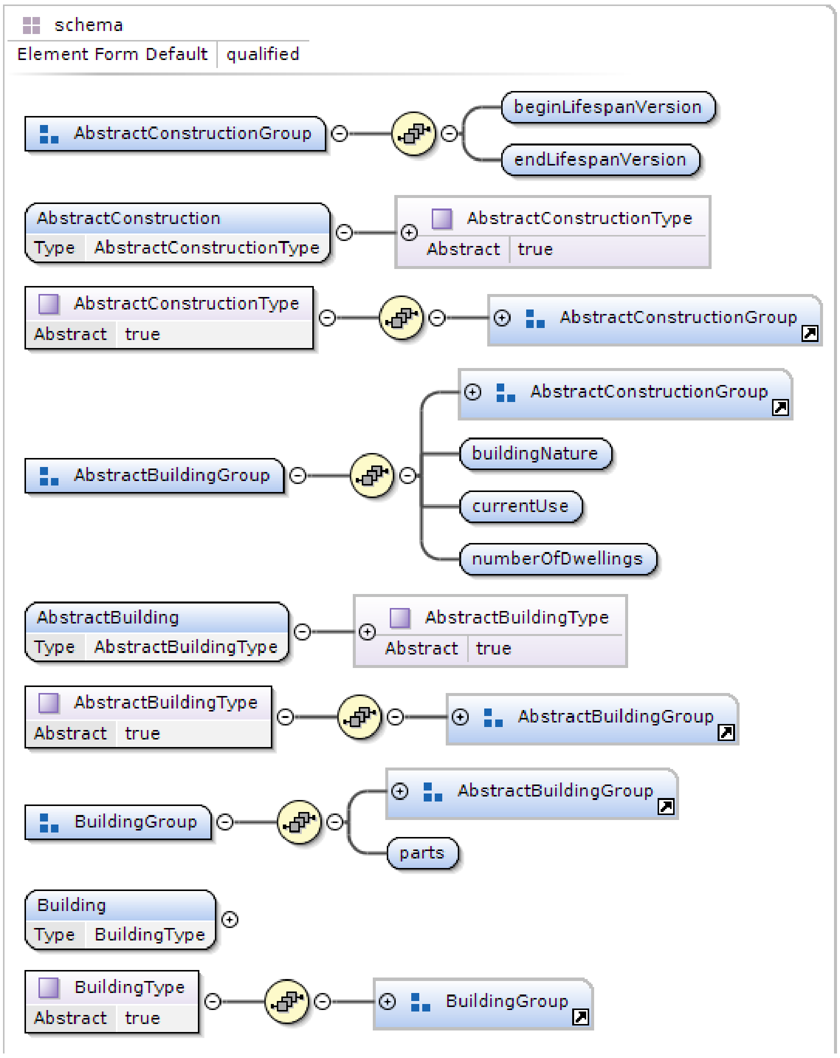


Figure 4.7: Reshaped part of XSD for application schema Buildings base using groups shown in the oXygen software design view.

Other possibility of a solution is using an element with a complex type in other complex type. There are no additional elements or attributes related to the multiple inheritance. Part of the content of a new complex type is inherited and the other part is enclosed

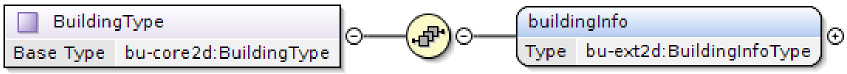


Figure 4.8: Using complex type as a type of element for other complex type (shown in the oXygen software design view).

within new element with a given type, as seen in the Figure 4.8. All elements with type `BuildingType` inherits everything from type `bu-core2d:BuildingType` (representation of **BuildingsBase2D::BuildingType**) with one additional element `buildingInfo`, that inherits everything from `bu-ext2d:BuildingInfoType` (representation of ***BuildingsExtended2D::BuildingInfoType***). All elements and attributes defined in both complex types are preserved, moreover it is still possible to use the types as ascendants or descendants for definition of other types. The problem is that it is not inheritance as shown in the application schema model. Visualisation of the model using complex type workaround is shown in the Figure 4.9, while the property `buildingInfo` is not a reference, but the full content of ***BuildingsExtendedBase::BuildingInfo*** feature type as an attribute. This also means that ***BuildingsExtendedBase::BuildingInfo*** is represented as an element of **BuildingsCore2D::Building** and all its elements and attributes are parts of `buildingInfo` element. Why to choose `buildingInfo` as an element and not `building`?

1. `building` is already modeled in XSD for application schema Buildings 2D, where it is used as a standalone feature with identifier, geometry and life span version,

2. `buildingInfo` looks and behave more like an attribute (in a UML modelling point of view) than feature. So it is rather to be modeled as element of another type in XSD,

3. considering feature types objects defined by unique identifier with ability to be properly defined in space and time, `buildingInfo` is not this kind of feature type, but a property of a feature type.

During the time, there were also experiments extending the XML Schema in a way to support non-monotonic multiple inheritance, as is usual in object–oriented (programming) languages. Some authors write about extending XML Schemas ([26]). Anyway until now there is no functional extension of XSD that supports multiple inheritance. It is always connected with ambiguous representation of elements and types.

Based on the previous research, complex types are used to work around multiple inheritance problem in INSPIRE theme Buildings.

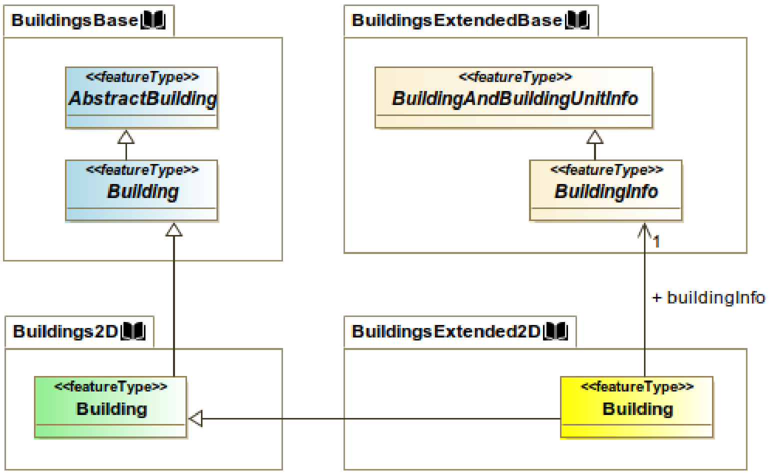


Figure 4.9: Changed model of relations between feature types using the complex type work around.

4.2.1.2 Design of XSD for Buildings extended base schema

One XSD file was created for every missing application schema. Based on the application schema hierarchy shown in the Figure 2.5, Buildings extended base schema extends Buildings base schema and is further extended by Buildings extended 2D and Buildings extended 3D schemas. Extension in the context of XML Schemas is realized as `import`.

According to the application schema Buildings extended base (as seen in the Figure 3.2), XSD file shall contain representation of feature types ***BuildingAndBuildingUnitInfo***, ***AbstractBuildingUnit***, ***BuildingInfo***, ***AbstractOtherConstruction*** and ***Abstract-Installation***, all abstract.

First, namespaces and imports are defined:

```
<?xml version="1.0" encoding="UTF-8"?>
<schema elementFormDefault="qualified"
  targetNamespace="http://inspire.ec.europa.eu/schemas/bu-ext/4.0"
  xmlns="http://www.w3.org/2001/XMLSchema"
  xmlns:bu-base="http://inspire.ec.europa.eu/schemas/bu-base/4.0"
  xmlns:gmd="http://www.isotc211.org/2005/gmd"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:ad="http://inspire.ec.europa.eu/schemas/ad/4.0"
  xmlns:cp="http://inspire.ec.europa.eu/schemas/cp/4.0"
  xmlns:base="http://inspire.ec.europa.eu/schemas/base/3.3"
  xmlns:base2="http://inspire.ec.europa.eu/schemas/base2/1.0"
  xmlns:bu-ext="http://inspire.ec.europa.eu/schemas/bu-ext/4.0">
  <import namespace="http://inspire.ec.europa.eu/schemas/bu-base/4.0"
    schemaLocation="http://inspire.ec.europa.eu/schemas/bu-base/4.0/BuildingsBase.xsd"/>
```

```
  <import namespace="http://inspire.ec.europa.eu/schemas/base/3.3"
    schemaLocation="http://inspire.ec.europa.eu/schemas/base/3.3/BaseTypes.xsd"/>
  <import namespace="http://www.isotc211.org/2005/gmd"
    schemaLocation="http://schemas.opengis.net/iso/19139/20070417/gmd/gmd.xsd"/>
  <import namespace="http://www.opengis.net/gml/3.2"
    schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
  <import namespace="http://inspire.ec.europa.eu/schemas/gn/4.0"
    schemaLocation="http://inspire.ec.europa.eu/schemas/gn/4.0/GeographicalNames.xsd"/>
  <import namespace="http://inspire.ec.europa.eu/schemas/cp/4.0"
    schemaLocation="http://inspire.ec.europa.eu/schemas/cp/4.0/CadastralParcels.xsd"/>
  <import namespace="http://inspire.ec.europa.eu/schemas/ad/4.0"
    schemaLocation="http://inspire.ec.europa.eu/schemas/ad/4.0/Addresses.xsd"/>
  <import namespace="http://inspire.ec.europa.eu/schemas/base/3.3"
    schemaLocation="http://inspire.ec.europa.eu/schemas/base/3.3/BaseTypes.xsd"/>
  <import namespace="http://inspire.ec.europa.eu/schemas/base2/1.0"
    schemaLocation="http://inspire.ec.europa.eu/schemas/base2/1.0/BaseTypes2.xsd"/>
    ...
</schema>
```

Namespaces are used to shorten the URI for elements and types from imported XML Schemas. It is also possible to define namespace for current XSD, as `bu-ext` in this case. Among imports can be found GML and INSPIRE Base Types as well as XML Schemas for other INSPIRE themes. For extending INSPIRE Buildings it is crucial to import official Buildings base XSD file. It is neccessary to reuse elements and types from this XML Schema, because feature types ***AbstractOtherConstruction*** and ***AbstractInstallation*** inherits from feature type ***BuildingsBase::AbstractConstruction***. Starting with these two feature types, elements `AbstractInstallation` and `AbstractOtherConstruction` were created as follows:

```
 <element abstract="true" name="AbstractOtherConstruction"
    type="bu-ext:AbstractOtherConstructionType"
    substitutionGroup="bu-base:AbstractConstruction">
    <annotation>
      <documentation>
        -- Name --
        ...
      </documentation>
    </annotation>
  </element>

  <element abstract="true" name="AbstractInstallation"
    type="bu-ext:AbstractInstallationType"
    substitutionGroup="bu-base:AbstractConstruction">
    <annotation>
      <documentation>
        -- Name --
        ...
      </documentation>
    </annotation>
  </element>
```

Besides documentation, which was shorten in the example, both elements contain only attributes `abstract` (with value `true`), `name`, `type` and `substitutionGroup`. Attribute `type` defines a type of element content. It is defined in the schema with namespace `bu-ext`, which is current schema. Substitution group is a XSD construct allowing data modelers to substitute head element within the same group.

Important attribute of elements is their type. For both elements described above were created complex types `AbstractOtherConstructionType` and `AbstractInstallationType`.

```
<complexType abstract="true" name="AbstractOtherConstructionType" mixed="false">
    <complexContent>
      <extension base="bu-base:AbstractConstructionType">
        <sequence>
          <element name="otherConstructionNature">
            <annotation>
            <documentation>
              -- Name --
              ...
            </documentation>
            </annotation>
            <complexType>
              <complexContent>
                <extension base="gml:ReferenceType"> </extension>
              </complexContent>
            </complexType>
          </element>
        </sequence>
      </extension>
    </complexContent>
  </complexType>

  <complexType abstract="true" name="AbstractInstallationType">
    <complexContent>
      <extension base="bu-base:AbstractConstructionType">
        <sequence>
          <element name="installationNature">
            <annotation>
              <documentation>
                -- Name --
                ...
              </documentation>
            </annotation>
            <complexType>
              <complexContent>
                <extension base="gml:ReferenceType"> </extension>
              </complexContent>
            </complexType>
          </element>
        </sequence>
      </extension>
```

```
  </complexContent>
</complexType>
```

Both complex types have complex content – extensions or restrictions are allowed on complex types containing mixed content or elements only. Simple content can extend or restrict only complex type containing only text or simple type with no elements.

`Base` attribute of the `extension` element defines the type that is extended. In both cases it is `AbstractConstructionType` from the XML Schema for application schema Buildings base – shortened by namespace `bu-base`. Without `extension` element, both complex types would contain only elements and attributes inherited from base type. Its content is like content of any other element – it includes compositor, attributes and elements. Both types uses `sequence` as a compositor with one element, while `AbstractOtherConstructionType` contains `otherConstructionNature` element and `AbstractInstallationType` contains `installationNature` element. Based on the application model, those elements shall contain a value from a code lists defined in the Data specification document – `otherConstructionNatureValue` and `installationNatureValue`. Values of code lists are in the Annex C of the Data specification document and shall be available through web application for INSPIRE registers available at `http://inspire.ec.europa.eu/codelist/`. By the time of writing of this dissertation thesis, none of code lists defined for feature types from application schema Buildings extended base exist in the register. Anyway, value of the element shall reference to the URI of the value (even if it is not resolvable) and it could be expected, that the code list URI will exist in the future. XML schema for GML defines `ReferenceType`, allowing reference to another object in URI form. Elements `otherConstructionNature` and `installationNature` have anonymous complex types [4] extending `gml:ReferenceType`. Output in XML based on the XSD file models `otherConstructionNature` elements like this:

```
<bu-ext:otherConstructionNature  xlink:title="retainingWall" xlink:href=
  "http://inspire.ec.europa.eu/codelist/OtherConstructionNatureValue/retainingWall"/>
```

Other three feature types to be included in XSD file are more complex, but do not extend any of the existing feature types. Feature type ***BuildingAndBuildingUnitInfo*** associates all basic information about both extended buildings and newly defined building units. Attributes and elements specific only for buildings or building units are defined in its descendants ***BuildingInfo*** and ***AbstractBuildingUnit***.

Feature type ***BuildingAndBuildingUnitInfo*** is not extension of any feature type defined in the theme Buildings. All feature types representing geometric objects using GML are extensions of *`gml:AbstractFeatureType`* complex type. Feature types inheriting from application schema Buildings have this ensured by their ancestors, because complex type `AbstractConstructionType` from the XSD file for Buildings base is an extension of *`gml:AbstractFeatureType`*. Every feature of this type may be spatially determined using properties defined in GML XML Schema. For building and building unit info element

[4] Using anonymous complex type is advantageous for one time use of a type, that usually extends other complex types (by adding attributes etc.).

it seems unneccessary based on the fact, that it does not represent spatial object, only information about it. According to the original model of feature types (shown in Figure 4.6), its descendants may be spatial objects. It is kept this way despite the fact that ***BuildingInfo*** feature type is only referenced (not inherited) by the **Building** and **BuildingPart** feature types from application schemas Buildings extended 2D and buildings extended 3D (as a solution of multiple inheritance problem).

Based on the analysis done in the Section 3.1.1.2 and schema shown in the Figure 3.2, feature type ***BuildingAndBuildingUnitInfo*** shall contain attributes `connectionToElectricity`, `connectionToGas`, `connectionToSewage`, `connectionToWater`, `document`, `energyPerformance`,`heatingSource`, `heatingSystem`, `address`, `officialArea` and `officialValue`. It also contains two association roles.

All previously listed attributes and association role `cadastralParcel` are modeled as elements within `sequence` compositor, while none of the elements is obligatory (minimum number of occurrences is always 0). Association role `address` is represented by its aggregation to the attribute `address`. For the descriptive purposes, attributes are divided into group 'connection to networks' (`connectionToElectricity`, `connectionToGas`, `connectionToSewage` and `connectionToWater`) and other attributes `document` and association roles.

Group 'connection to networks' needs only one information – is a building connected or not? They are modeled as anonymous complex types with simple content – extension of `boolean` type with added attribute `nilReason`. Allowed value of elements with such type is `true` or `false`, or it may be left empty with attribute `xsi:nil` set to `true`. This means, that information is either unknown or not collected for the data set (which is specified using `nilReason` attribute as described in Section 3.2.1). The XSD is represented this way:

```
<element minOccurs="0" name="connectionToElectricity" nillable="true">
  <annotation>
    <documentation>
      -- Name --
      Connection to electricity

      -- Definition --
      ...
    </documentation>
  </annotation>
  <complexType>
    <simpleContent>
      <extension base="boolean">
        <attribute name="nilReason" type="gml:NilReasonType"/>
      </extension>
    </simpleContent>
  </complexType>
</element>
```

Other attributes are represented as elements with own defined complex types or as references to either code lists or other features. Elements using `gml:ReferenceType` are `heatingSource` and `heatingSystem`, partly `address` and `cadastralParcel`. First two types references code list values defined in Data specification document. Newly defined data types are `DocumentType`, `EnergyPerformanceType`, `OfficialAreaType` and `OfficialValueType`. Those types are defined within the same XSD file and their content corresponds to the description of types in Data specification document. Creation of types is the same as in the case of ***BuildingAndBuildingUnitInfo*** with exception that new types have no base type.

Data type `DocumentType` contains four attributes: `documentLink` with `anyURI` type, `date` with `dateTime` type, `documentDescription` with `gmd:PT_FreeText_PropertyType`, that allows multiple languages and `sourceStatus` with `gml:ReferenceType`, indicating if document comes from the official source. All attributes are modeled as elements within `sequence` compositor. Definition of document type in XSD looks like this:

```
<complexType name="DocumentType">
  <sequence>
    <element name="documentLink" type="anyURI">
      <annotation>
        <documentation>
          ...
        </documentation>
      </annotation>
    </element>
    <element minOccurs="0" name="date" nillable="true">
      <annotation>
        <documentation>
          ...
        </documentation>
      </annotation>
      <complexType>
        <simpleContent>
          <extension base="dateTime">
            <attribute name="nilReason" type="gml:NilReasonType"/>
          </extension>
        </simpleContent>
      </complexType>
    </element>
    <element minOccurs="0" name="documentDescription" nillable="true">
      <annotation>
        <documentation>
          ...
        </documentation>
      </annotation>
      <complexType>
        <complexContent>
          <extension base="gmd:PT_FreeText_PropertyType">
            <attribute name="nilReason" type="gml:NilReasonType"/>
          </extension>
```

```
        </complexContent>
      </complexType>
    </element>
    <element minOccurs="1" name="sourceStatus" nillable="true">
      <annotation>
        <documentation>
          ...
        </documentation>
      </annotation>
      <complexType>
        <complexContent>
          <extension base="gml:ReferenceType"> </extension>
        </complexContent>
      </complexType>
    </element>
  </sequence>
</complexType>
```

Type `EnergyPerformanceType` contains three obligatory attributes – `energyPerformanceValue` with `gml:ReferenceType`, `dateOfAssessment` with `dateTime` type and `assessmentMethod` with `base2:documentCitationType`. Type `OfficialAreaType` contains two obligatory attributes – `value` with `gml:AreaType` and `officialAreaReference` with `gml:ReferenceType` – and attribute `heightParameter` with `gml:LengthType` with cardinality 0..1. Type `OfficialValueType` have six obligatory attributes – `value` with `integer` type, `currency` with `gml:ReferenceType`, `officialValueReference` with `gml:ReferenceType`, `valuationDate` with `dateTime` type, `referencePercentage` with `integer` type and `informationSystemName` with `gmd:PT_FreeText_Type`. All elements with `gml:ReferenceType` references to code lists defined in Annex C of Data specification document. Architecture of types is the same as in the `DocumentType` example.

Association roles `address` and `cadastralParcels` are implemented as a reference type with possibility to express the referenced feature as an object. In the case of `address`, which is also a stand alone attribute with `ad:AddressRepresentationPropertyType` from XSD file for application schema Addresses, it is done by extension of type by adding `gml:AssociationAttributeGroup`. Attribute groups are named sets of attributes. This particular attribute group contains attributes `nilReason` and `gml:remoteSchema` and other attribute group `xlink:simpleAttrs`. Basically it allows element of this type to be left empty with reference to other object. In XSD it looks like this:

```
<element maxOccurs="unbounded" minOccurs="0" name="address" nillable="true">
  <annotation>
    <documentation>
      -- Name --
      Address

      --  Definition --
      The address(es) of the building or building part or building unit.
    </documentation>
  </annotation>
```

```
  <complexType>
    <complexContent>
      <extension base="ad:AddressRepresentationPropertyType">
        <attributeGroup ref="gml:AssociationAttributeGroup"/>
      </extension>
    </complexContent>
  </complexType>
</element>
```

Data represented by element address may then look as one of the following examples. First example is primarily used for expressing address by municipality and/or municipal part. Second example is link straight to the address feature. It is legal to use both examples at once.

```
<bu-ext:address>
  <ad:AddressRepresentation>
    <ad:adminUnit>
      <gn:GeographicalName>
        <gn:language>ces</gn:language>
        <gn:nativeness
          xlink:href="http://inspire.ec.europa.eu/codelist/NativenessValue/endonym"
          xlink:title="endonym" />
        <gn:nameStatus
          xlink:href="http://inspire.ec.europa.eu/codelist/NameStatusValue/official"
          xlink:title="official" />
        <gn:sourceOfName>esk ad zemmick a katastrln</gn:sourceOfName>
        <gn:pronunciation
          xsi:nil="true"
          nilReason="http://inspire.ec.europa.eu/codelist/VoidReasonValue/Unpopulated"/>
        <gn:spelling>
          <gn:SpellingOfName>
            <gn:text>Abertamy</gn:text>
            <gn:script>Latn</gn:script>
          </gn:SpellingOfName>
        </gn:spelling>
      </gn:GeographicalName>
    </ad:adminUnit>
    <ad:addressArea>
      <gn:GeographicalName>
        <gn:language>ces</gn:language>
        <gn:nativeness
          xlink:href="http://inspire.ec.europa.eu/codelist/NativenessValue/endonym"
          xlink:title="endonym" />
        <gn:nameStatus
          xlink:href="http://inspire.ec.europa.eu/codelist/NameStatusValue/official"
          xlink:title="official" />
        <gn:sourceOfName>esk ad zemmick a katastrln</gn:sourceOfName>
        <gn:pronunciation
          xsi:nil="true"
          nilReason="http://inspire.ec.europa.eu/codelist/VoidReasonValue/Unpopulated"/>
        <gn:spelling>
```

```
        <gn:SpellingOfName>
          <gn:text>Abertamy</gn:text>
          <gn:script>Latn</gn:script>
        </gn:SpellingOfName>
      </gn:spelling>
    </gn:GeographicalName>
  </ad:addressArea>
 </ad:AddressRepresentation>
</bu-ext:address>

<bu-ext:address
 xsi:nil="true"
 xlink:href="http://services.cuzk.cz/wfs/inspire-cp-wfs.asp?service=WFS&VERSION=2.0.0&
 request=GetFeature&storedQuery_id=urn:ogc:def:query:OGC-WFS::GetFeatureById&
 Id=AD.11883600"/>
```

Association role `cadastralParcel` is implemented the same way by including `cp:CadastralParcel` element and `gml:AssociationAttributeGroup`, allowing either reference to the Cadastral parcel object or including the object itself, in this case `CadastralParcel` feature.

Feature types ***BuildingInfo*** and ***AbstractBuildingUnit*** are extensions of ***BuildingAndBuildingUnitInfo***. Both feature types are represented as abstract elements with abstract complex types with `BuildingAndBuildingUnitInfoType` as a base type. Feature type ***BuildingInfoType*** contains attributes `floorDescription`, `floorDistribution`, `heightBelowGround`, `materialOfFacade`, `materialOfRoof`, `materialOfStructure`, `numberOfFloorsBelowGround`, `roofType` and association roles `buildingUnit` and `installation`. Feature type ***AbstractBuildingUnit*** contains attributes `inspireId`, `externalReference`, `currentUse`, `beginLifeSpanVersion` and `endLifeSpanVersion`.

Feature type ***BuildingInfoType*** expresses information about existing building, while ***AbstractBuildinUnit*** is an abstract type to be expressed as a stand alone object representing building unit.

Feature type ***AbstractBuildingUnit*** shall contain same attributes as every INSPIRE object, except geometry. Modelling of such feature type in XSD is done same way as feature types ***AbstractOtherConstruction*** and ***AbstractInstallation***. Complex type `AbstractBuildingUnitType` has `BuildingAndBuildingUnitInfo` as a base type, content is complex with `sequence` compositor and all attributes are modeled as elements. All named elements were already used in XSD file for application schema Buildings base and complex type `AbstractBuildingUnitType` reuses those types.

Feature type ***BuildingInfo*** extends information about buildings by attributes divisible into two groups – underground description with attributes `heightBelowGround` and `num-`

berOfFloorsBelowGround, and material information containing attributes materialOf-Facade, materialOfRoof and materialOfStructure. Stand alone attributes are floor-Description and floorDistribution. Last attribute – roofType – is thematically stand alone, but functionally belongs among materials information.

Materials information attributes and roofType have gml:ReferenceType and refere to code lists containing materials, their carinality is 0..∞. Code lists are described in the Annex C of Data specification document on Buildings. Underground description attributes have numeric types – integer for number of floors below ground and gml:LengthType for height below ground. Both elements have cardinality 0..1. Finally, stand alone attributes describe distribution of floors by newly defined complex type FloorRangeType with two obligatory attributes – lowestFloor and highestFloor, both with double type. FloorDistribution element is obligatory. Moreover, FloorDescription provides additional information about floors with same characterictics using newly defined complex type FloorDescriptionType with elements floorRange, areaOfOpenings, currentUse, document, floorArea, height and numberOfDwellings. Association types buildingUnit and installation are implemented as elements with anonymous complex type containing specific feature (AbstractBuildingUnit or AbstractInstallation) and gml:Association-AttributeGroup.

Newly created XSD file must be placed publicly to the world wide web and identified within other schemas. Identification of the schema is done using targetNamespace attribute in the element schema – the root element of the XSD file. The identifier of XSD file describing application schema Buildings extended base is http://inspire.ec.europa.eu/-schemas/bu-ext/4.0. This identifier is used to import this file into another schema. In order to allow dereferencing of URIs, XSD file shall be places on the same address. URI is also the base of the identifier of every object defined inside the file, e.g. complex type BuildingAndBuildingUnitInfos full identifier is http://inspire.ec.europa.eu/schemas/bu-ext/4.0/BuildingAndBuildingUnitInfo, by which it has to be addressed in other schemas (or shortened using xml namespace short).

All feature types defined in the application schema Buildings extended base are abstract, thus they may not have instances. Only non–abstract feature types may have instances. Concrete feature types are defined in application schemas Buildings extended 2D and Buildings extended 3D. XSD files for those schemas import http://inspire.ec.europa.eu/-schemas/bu-ext/4.0.

4.2.1.3 Design of XSD for Buildings extended 2D schema

XSD file implementing Buildings extended 2D application schema have target namespace (identifier) http://inspire.ec.europa.eu/schemas/bu-ext2d/4.0. It imports only schema for GML and XSD files implementing application schemas Buildings core 2D and Buildings extended base. Other needed imports are inherited from Buildings extended base schema.

```
<schema elementFormDefault="qualified"
  targetNamespace="http://inspire.ec.europa.eu/schemas/bu-ext2d/4.0">
  <import namespace="http://inspire.ec.europa.eu/schemas/bu-core2d/4.0"
    schemaLocation="http://inspire.ec.europa.eu/schemas/bu-core2d/4.0/BuildingsCore2D.xsd"/>
  <import namespace="http://inspire.ec.europa.eu/schemas/bu-ext/4.0"
    schemaLocation="http://services.cuzk.cz/xsd/inspire/bu-ext/4.0/BuildingsExtendedBase.xsd"/>
  <import namespace="http://www.opengis.net/gml/3.2"
    schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
    ...
</schema>
```

All abstract feature types from Buildings extended base schema have their concrete realization in Buildings extended 2D, namely it is **Building**, **BuildingPart**, **BuildingUnit**, **Installation**, **OtherConstruction** and **BuildingInfo**. Technical realization of such feature types is done by extending the abstract type by adding geometry element. This is the same for XSD files representing both Buildings extended 2D and Buildings extended 3D, only in the later mentioned, geometry is represented by various types for levels of detail of the geometry. Buildings extended 3D also contains some more feature types for 3D representation of objects. For **BuildingUnit**, **Installation** and **OtherConstruction**, realization is shown in the Figure 4.10 on the example of concretization of abstract feature type ***BuildingsExtendedBase::OtherConstructionType*** and in the following example.

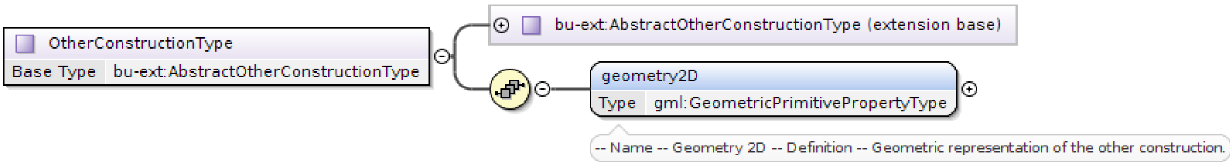


Figure 4.10: Concretization of abstract feature type ***BuildingsExtendedBase::OtherConstructionType*** in XML Schema BuildingsExtended2D by extending its content by `geometry2D` element.

```
<complexType name="OtherConstructionType">
  <complexContent>
   <extension base="bu-ext:AbstractOtherConstructionType">
     <sequence>
       <element name="geometry2D" type="gml:GeometricPrimitivePropertyType">
         <annotation>
           <documentation>-- Name --
  Geometry 2D

  -- Definition --
  Geometric representation of the other construction.</documentation>
         </annotation>
       </element>
     </sequence>
   </extension>
```

```
  </complexContent>
</complexType>
```

Feature types **Building** and **BuildingInfo** have however problem with multiple inheritance, that is descibed earlier in the Section 4.2.1.1. Feature types **Building** and **BuildingPart** inherit from the feature type of the same name from application schema Buildings 2D and from ***BuildingInfo*** feature type from application schema Buildings extended base. Solution is replacing inheritance of ***BuildingInfo*** by an element with ***BuildingsExtendedBase::BuildingInfoType***, as shown in the Figure 4.9, or its extension. Solution used in Buildings extended 2D for the feature type **Building** follows:

```
<complexType name="BuildingType">
  <complexContent>
    <extension base="bu-core2d:BuildingType">
      <sequence>
        <element name="buildingInfo" type="bu-ext2d:BuildingInfoType"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>

<complexType name="BuildingInfoType">
  <complexContent>
    <extension base="bu-ext:BuildingInfoType"/>
  </complexContent>
</complexType>
```

The previous example shows **BuildingsExtended2D::BuildingType** extending **Buildings2D::BuildingType** with element `buildingInfo` of type **BuildingsExtended2D::BuildingInfoT** This type is defined within XML Schema for application schema Buildings extended 2Das extension of ***BuildingsExtendedBase::BuildingInfoType*** with no additional elements or attributes in order to easily manage possible further extensions of **BuildingsExtended2D::BuildingInfoType**.

In order to provide data for INSPIRE theme Buildings with respect to the existing data provided for Buildings in the Czech Republic, especially to the information needed and used by national users, two additional application schemas with corresponding XML Schemas were created. Guarantee of data for Buildings in the Czech Republic – Czech Office for Surveying, Mapping and Cadastre – provides only 2D data. All newly created schemas are available at `http://services.cuzk.cz/xsd/inspire/`.

4.2.1.4 Buildings extended base and Buildings extended 2D XML Schema evaluation

Schema for Buildings extended 3D is not needed for the modelling of INSPIRE data provided by Czech guarantee of the theme Buildings. However, technical realization of this application schema via XML Schema is not very different from realization of Buildings extended 2D. Basic feature types are the same as in Buildings extended 2D, reusing same abstract feature types from Buildings extended base. Next to the optional 2D geometry, feature types from Buildings extended 3D contain representation of 3D geometry depending on the level of detail of geometry (shown in the Figure 3.6). Besides reusing types from Buildings extended base and Buildings 3D schema, Buildings extended 3D defines new feature types and data types for representation of building components based on the level of detail and appereance. Anyway, it is not part of this dissertation thesis, because it focuses on the implementation of INSPIRE in the context of SDI in the Czech Republic.

4.2.2 XML Schemas for extension of Cadastral Parcels

The basis for the XML Schema Cadastral Parcels Extended is newly created application schema – an extension of Cadastral Parcels – that was created as a part of this dissertation thesis. Therefore it is easier to fix possible problems. On the other hand, there is no source to build on. Application schema extends schema Cadastral Parcels. In the same way, XSD file imports and extends Cadastral Parcels XSD.

Design of the application schema is described in the Section 4.1 and is based on the content of the Cadastral map, content of the databases in which the data about cadastre are stored and on the needs of national users. The application schema contains several basic feature types:

- **CadastralParcel** (details in 4.2.2.1),
- **CadastralBoundary** (details in 4.2.2.2),
- **CadastralZoning** (details in 4.2.2.3),
- **AnalogueCadastralParcel** (details in 4.2.2.4),
- **Easement** (details in 4.2.2.5),
- **GeodeticPoint** (details in 4.2.2.6),
- ***OtherFeature*** with its specializations (details in 4.2.2.7) and
- ***OriginalGeometry*** with its specializations (details in 4.2.2.8).

Both abstract feature types ***OtherFeature*** and ***OriginalGeometry*** have concrete feature types as descedants.

Some of the elements have one of Base data types – types that are specific for INSPIRE, but common for more themes, e.g. inspire identifier. Those data types are stored in the XSD files INSPIRE Base types and INSPIRE Base types 2. Most of XSD files for INSPIRE themes import those files – `http://inspire.ec.europa.eu/schemas/base/3.3/BaseTypes.xsd`and `http://inspire.ec.europa.eu/schemas/base2/1.0/BaseTypes2.xsd`.

Although, for the needs of Cadastral Parcels Extended were created new data types, specific for the environment of Czech Office for Surveying, Mapping and Cadastre. Those types are stored in newly created XSD file Cuzk types. This file is available at `http://services.cuzk.cz/xsd/inspire/cuzkTypes/1.0/cuzkTypes.xsd`. All new types are shown in the Figure 4.11 and described further in the text, accompanying description of the feature types using it.

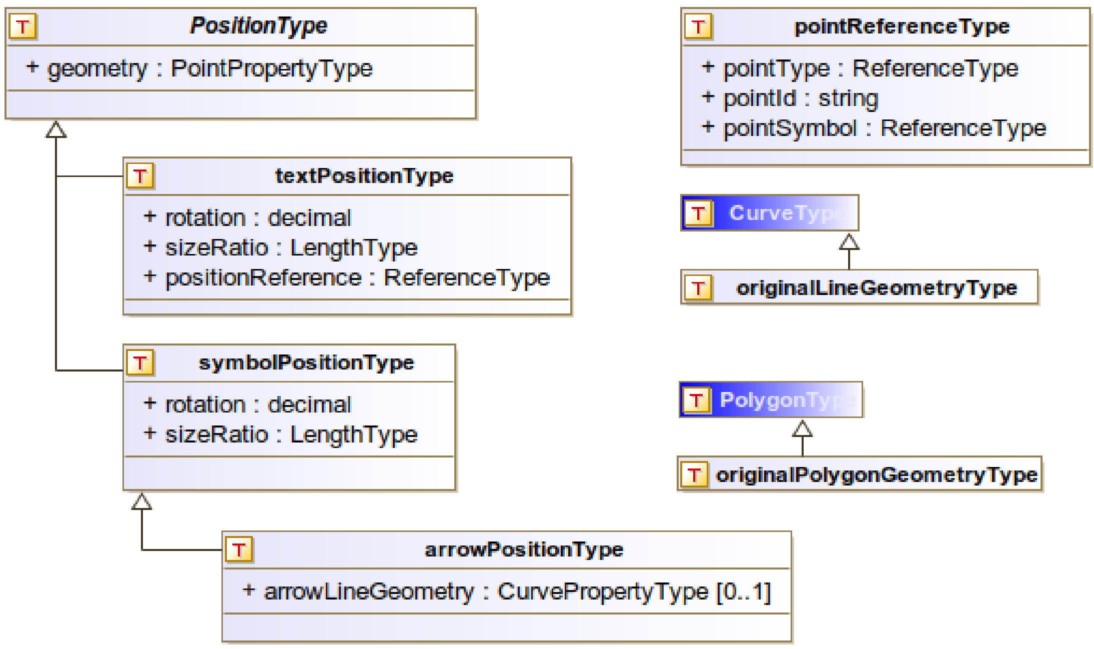


Figure 4.11: New data types created for implementation of Cadastral Parcels Extended (in grey). Dark blue types come from GML XML Schema.

Some of the INSPIRE data attributes refer to the values from code lists. There is a register at URI `http://inspire.ec.europa.eu/codelist` containing all INSPIRE specific code lists and their values. Data of Cadastral Parcels Extended have values based on the code list values from the cadastral database. It is also important to create new INSPIRE code lists and map those values in a form of URI to cadastral database code lists. For this purpose was created code list register of Czech Office for Surveying, Mapping and Cadastre. Code list register is accessible from `https://services.cuzk.cz/registry/codelist`. Code lists and their values are accessible in a form of HTML page, XML document or JSON file, all in both english and czech language. Besides other attributes (such as validity, title, description), code list values contain mapping to the original cadastral database code list. Values of some code lists contain more additional information described further in the text, accompanying description of the feature types using it. Example of HTML page with code list value is in the Figure 4.12.

Figure 4.12: Code list value for the land type symbol of garden with identifier `https://services.cuzk.cz/registry/codelist/LandTypeSymbolValue/Garden` as an HTML page. It also contains link to the symbol image itself.

A lot of concepts are present in more than one feature type. Such concepts are described in detail in the first place in further text where it appears.

4.2.2.1 Extension of Cadastral parcel

CadastralParcel feature type has type **CadastralParcelType** that extends existing feature type **CadastralParcels::CadastralParcelType**. This new feature type defines new elements using sequence compositor, seen in Figure 4.13.

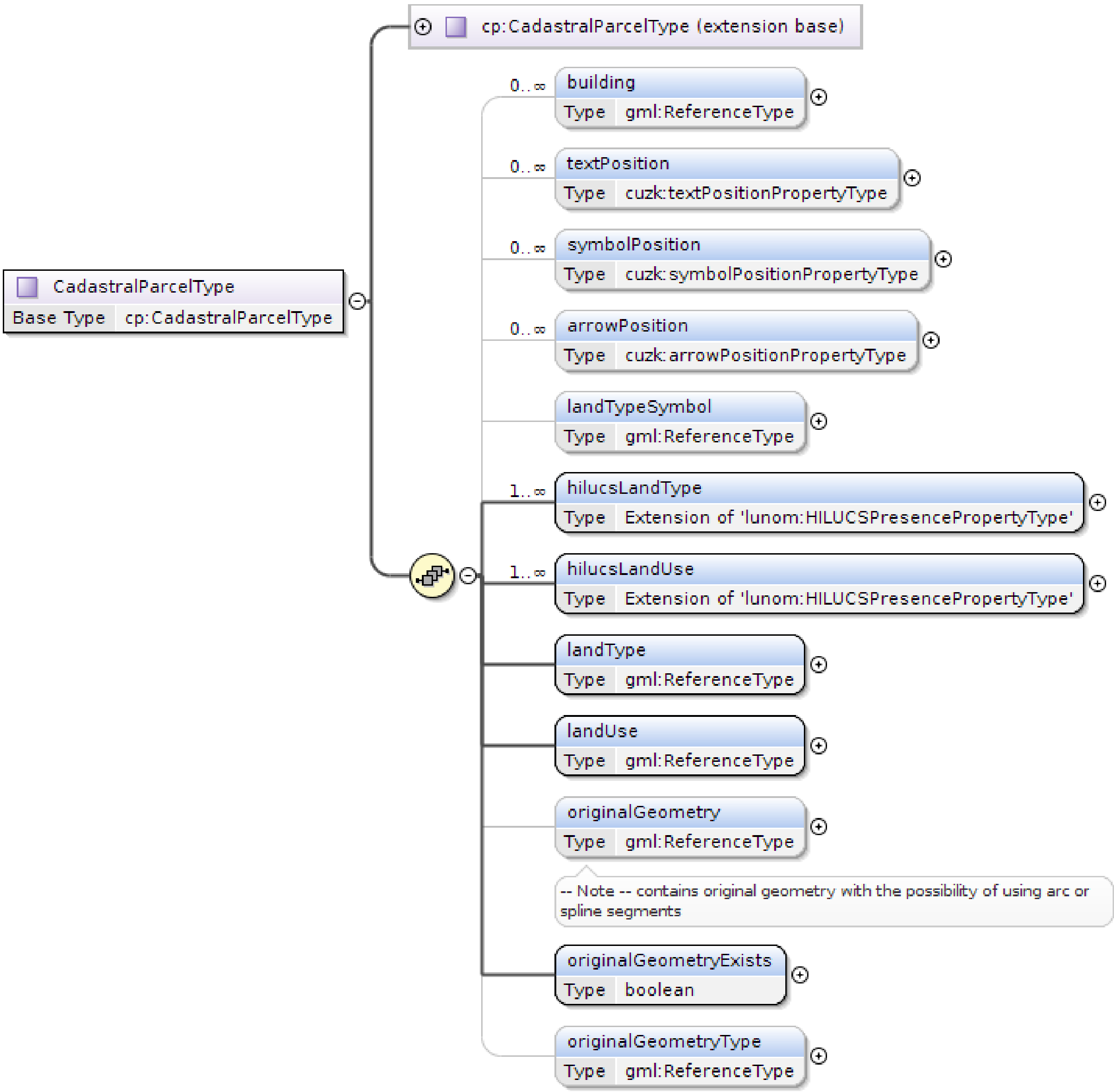


Figure 4.13: Realization of **CadastralParcelsExtended::CadastralParcelType** in XSD shown in oXygen software design view.

Note that elements `textPosition`, `symbolPosition` and `arrowPosition` have type with prefix `cuzk`. This prefix is set to namespace of XSD file located at `http://services.cuzk.cz/xsd/inspire/cuzkTypes/1.0/cuzkTypes.xsd`. These types are shown in the Figure 4.11 and their detailed description follows.

All are extensions of abstract type ***PositionType***, holding single element with point geometry. Geometry represents a place in a map where a map element is located. Map elements are texts, arrows and symbols, all seen in the Figure 3.19. Concrete types have several kinds of elements (examples are given further in the text of this Section):

- `rotation` – defines the angle of symbol rotation, e.g. name of the watercourse is oriented along the flow,
- `sizeRatio` – all symbols have default size, this value defines the ratio allowing symbol to change size,
- `positionReference` – defines which reference point of the text corresponds to the geometry. This element acquires value from the code list `http://services.cuzk.cz/registry/codelist/TextPositionReferenceValue/`, e.g. middle bottom, bottom left or upper right,
- `arrowLineGeometry` – arrow may contain auxiliary line represented as a `gml:Curve`.

Properties defining rotation, size ratio, symbol position reference and auxiliary arrow line are reused from the ISKN database, as described in the dissertation thesis of Jiří Bartoš [27]. The attributes are encoded in the *SDO_GEOMETRY* attribute in ISKN database. In the GML data, rotation has `double` value in degrees counterclockwise, size ratio is ratio to rescale default size of the symbol and position reference has value from the code list within the `xlink:href` attribute.

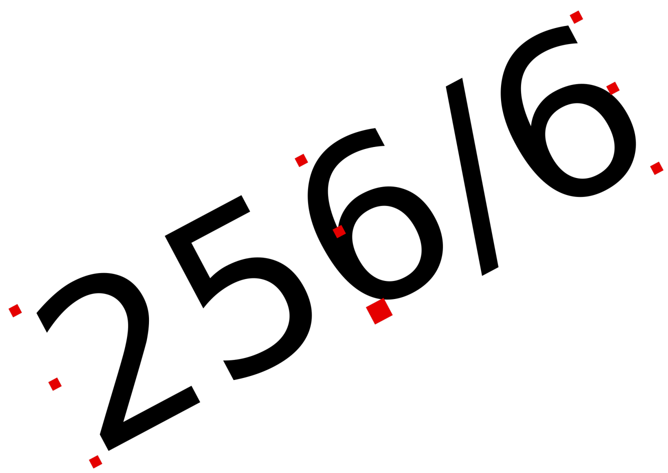


Figure 4.14: Example of a text with rotation 28 degrees. Red squares are points to reference position. Biggest one represents middle bottom.

In order to demonstrate usage of those elements are given two examples. In the first example (shown in the Figure 4.14) is a parcel number text with `rotation` set to 28 and

`positionReference` value is `http://services.cuzk.cz/registry/codelist/TextPositionReferenc`
`BottomMiddle`. Coordinates given to the symbol corresponds to the big red square in the Figure 4.14. Representation of this example in GML:

```
<cp-ext:textPosition>
  <cuzk:textPosition>
    <cuzk:geometry>
      <gml:Point gml:id="TP.CPX.1758030701"
          srsName="urn:ogc:def:crs:EPSG::5514" srsDimension="2">
        <gml:pos>-593329.15 -1149006.97</gml:pos>
      </gml:Point>
    </cuzk:geometry>
    <cuzk:rotation>28</cuzk:rotation>
    <cuzk:sizeRatio uom="m">1</cuzk:sizeRatio>
    <cuzk:positionReference xlink:href=
      "http://services.cuzk.cz/registry/codelist/TextPositionReferenceValue/BottomMiddle"/>
  </cuzk:textPosition>
</cp-ext:textPosition>
```

Note that text itself is not part of `textPosition` element. This element bears only information about its position. Text itself is value of the attribute `label` from the original **CadastralParcel** feature type.

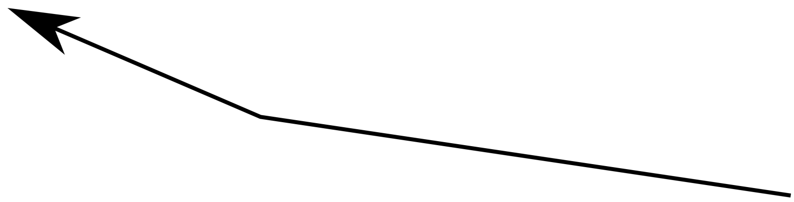


Figure 4.15: Appearance of an arrow with auxiliary line.

Second example represents arrow and its line:

```
<cp-ext:arrowPosition>
  <cuzk:arrowPosition>
    <cuzk:geometry>
      <gml:Point gml:id="AP.CPX.1758030701" srsName="urn:ogc:def:crs:EPSG::5514">
        <gml:pos>-593322.34 -1149007.9</gml:pos>
      </gml:Point>
    </cuzk:geometry>
    <cuzk:rotation>75</cuzk:rotation>
    <cuzk:sizeRatio uom="ratio">1</cuzk:sizeRatio>
    <cuzk:arrowLineGeometry>
      <gml:Curve gml:id="ALG.CPX.1758030701" srsName="urn:ogc:def:crs:EPSG::5514">
        <gml:segments>
          <gml:LineStringSegment>
            <gml:posList>-593319.54 -1149008.64 -593322.34 -1149007.9</gml:posList>
```

```
        </gml:LineStringSegment>
      </gml:segments>
    </gml:Curve>
  </cuzk:arrowLineGeometry>
  </cuzk:arrowPosition>
</cp-ext:arrowPosition>
```

The example shows a geometry position of an arrow itself with rotation value set to 75 and size ratio equal one, meaning default arrow (which points up) is turned 75 degrees counterclockwise and default size of the symbol is kept. Then there is `arrowLineGeometry` representing line. Note that one of the lines vertices geometry is equal to the position of arrow symbol. The appearence of the whole arrow (including auxiliary line) is similar to the one in the Figure 4.15. Note that arrow symbol does not have `positionReference` attribute. It always bound to middle bottom.

Arrow is a special type of symbol representation in a way, that it always uses arrow symbol[5]. Other symbols act the same, but have to be defined. It is done in the `landTypeSymbol` attribute of the **CadastralParcelType** feature type. Value of this attribute is a value from code list `https://services.cuzk.cz/registry/codelist/LandTypeSymbolValue/`. Code list value contains reference to the graphic file with symbol itself. Note that every **CadastralParcel** feature may contain several `textPosition`, `arrowPosition` and `symbolPosition` elements. All of them show the same text or symbol[6].

In INSPIRE, all land use values shall be linked to the Hierarchical INSPIRE Land Use Classification System (HILUCS) code list. It is in the INSPIRE code list register – `http://inspire.ec.europa.eu/codelist/HILUCSValue/`. According to the Czech Cadastral Law no. 256/2013 Sb., cadastral parcels have land type and land use. All possible values are listed in the Annex of the Cadastral Decree no. 357/2013 Sb. Both land type and land use values are now in the code list register of Czech Office for Surveying, Mapping and Cadastre as `https://services.cuzk.cz/registry/codelist/LandTypeValue/` and `https://services.cuzk.cz/registry/codelist/LandUseValue/`. In the register, values for both land use and land type are mapped into HILUCS values. Land use and land type values appears in `landUse` and `landType` elements as `xlink:href` reference to the codelist register, HILUCS values from INSPIRE code list register are referenced in `xlink:href` attributes of `hilucsLandUse` and `hilucsLandType` elements. For some parcels, land type or land use values may be missing. In such cases, those elements are nilled.

Elements `hilucsLandType` and `hilucsLandUse` reuse type `HILUCSPresencePropertyType` defined in XSD file realization of application schema Land use from the INSPIRE theme of the same name. It is complex type containing not only the value, but also a

[5] Symbol can be found at the code list value `https://services.cuzk.cz/registry/codelist/OtherFeatureTypeValue/ArrowToParcelNumber`.

[6] Arrow is usually pointing to the parcel number text.

percantage of particular land use on the given object. Czech Cadastre of Real Estates defines only one land use and land type per parcel, hence all are used by 100 percent.

Unlike INSPIRE, Czech Cadastre of Real Estates (including ISKN database) supports geometry with arc segments and circles and it is used by national users. Cadastral Parcels Extended XSD calls this geometry original geometry with own feature type described in the Section 4.2.2.8. In the `geometry` element of all features is geometry represented by line segments. Every feature type with possibility of having original geometry have three elements bound to it: `originalGeometryExists`, `originalGeometryType` and `originalGeometry`.

Boolean value of element `originalGeometryExists` defines if feature have original geometry segment. If and only if it has, other two elements appear. Attribute `xlink:href` of element `originalGeometryType` contains value from code list `http://services.cuzk.cz/registry/codelist/OriginalGeometryTypeValue/` defining type of original geometry. Finally, element `originalGeometry` references to the feature representing specific original geometry feature. Original geometry types are curve, enclosed circle, polynomial spline curve and compound polygon. It is important to distinguish the type, because geometry is represented differently.

4.2.2.2 Extension of Cadastral boundary

CadastralBoundary feature type has type **CadastralBoundaryType** extending feature type **CadastralParcels::CadastralBoundaryType** by the type of the boundary and original geometry, as seen in the Figure 4.16.

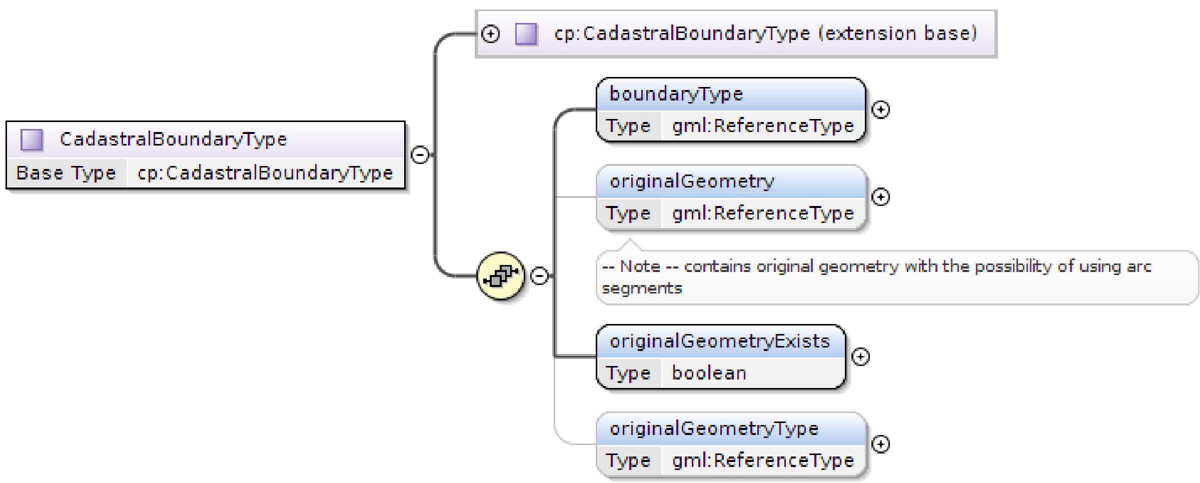


Figure 4.16: Realization of **CadastralParcelsExtended::CadastralBoundaryType** in XSD shown in oXygen software design view.

Type of boundary value is a reference to the code list `https://services.cuzk.cz/registry/codelist/BoundaryTypeValue`. Its values contain image representing the portrayal of a boundary with the given type, e.g. in the Figure 4.17 is visible state boundary line representation with symbol in the middle.

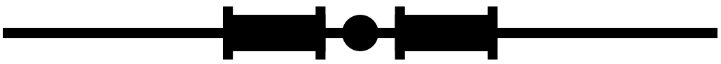


Figure 4.17: State boundary with symbol in the middle – line representation.

4.2.2.3 Extension of Cadastral zoning

Feature type **CadastralZoning** is exactly the same as in the application schema Cadastral Parcels. It occurs in the XSD file for Cadastral Parcels Extended because of the technical solution of web services provided by the company Geovap. This technical solution supports `describeFeatureType` request from the WFS service only for feature types that are defined in the same XML schema. Otherwise it provides link to the schema containing the feature type. The only feature type reused form other schema is **CadastralZoning**. The easiest solution of the problem is to create new feature type in the Cadastral Parcels extended XML schema with `CadastralZoningType` and make it blank extension of `CadastralZoningType` from Cadastral Parcels. More about the services is in the Chapter 5.

4.2.2.4 Analogue cadastral parcel

Althought most of the parcels in the ISKN database are already digitized (up to the 4th November 2019, 96.61 % of the coverage of the Czech Republic is already digitized accoring to the cadastral database), some number of cadastral parcels is still present only in analogue maps. Analogue cadastral parcels attributes are mixture of attributes from feature type **CadastralParcels::CadastralParcel** and **CadastralParcelsExtended::CadastralParcel** with point geometry, thus there is also no original geometry, no land type symbol and no position references for text or arrow. Complex type `AnalogueCadastralParcel` in the XSD file is direct extension of `gml:AbstractFeatureType`.

4.2.2.5 Easement

Next new feature type is **Easement**. Technical realization of its type is direct extension of *`gml:AbstractFeatureType`* and its schema in oXygen design view is in the Figure 4.18. Besides the basic elements `inspireId` and life cycle information, easements contain information about easement type, reference to cadastral parcel and original geometry.

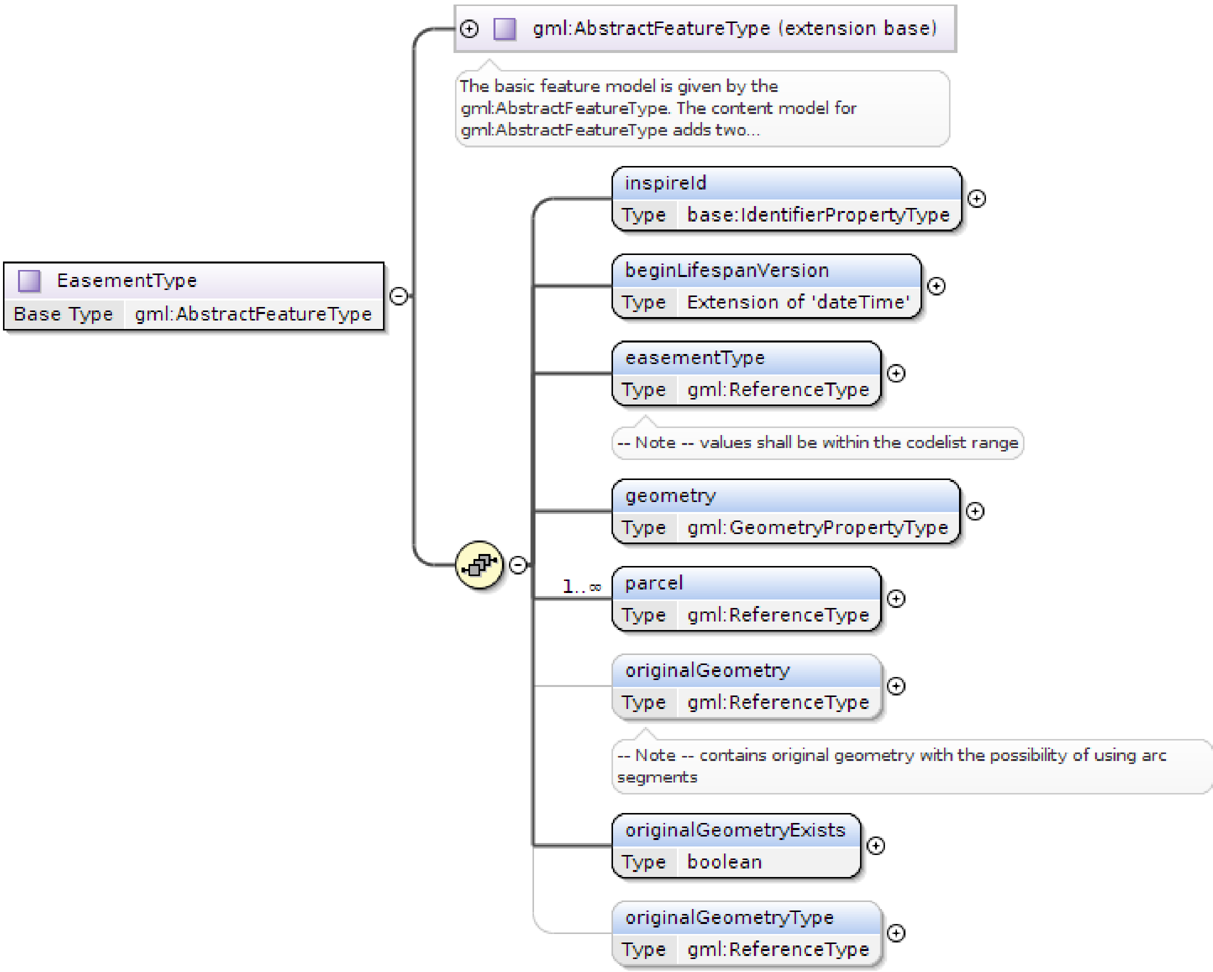


Figure 4.18: Realization of complex type **CadastralParcelsExtended::EasementType** in XSD shown in oXygen software design view.

Element `easementType` refers to the code list `https://services.cuzk.cz/registry/codelist/EasementTypeValue` with types of easements and their definitions. It contains over 30 types defined in various laws. Code list values contain also information about symbolology, but easements of all types are drawn with the same type line.

Easement may affect a whole parcel, its part or multiple parcel parts. Element `parcel` contain `xlink:href` reference to one or more parcels in a form of WFS service request. Example of concrete specific element is here:

```
<cp-ext:Easement gml:id="EA.24558551010">
  <cp-ext:inspireId>
    <base:Identifier>
      <base:localId>EA.24558551010</base:localId>
      <base:namespace>CZ-00025712-CUZK_CPX</base:namespace>
```

```
    </base:Identifier>
  </cp-ext:inspireId>
  <cp-ext:beginLifespanVersion>2016-10-25T07:06:24Z</cp-ext:beginLifespanVersion>
  <cp-ext:easementType xlink:href=
     "https://services.cuzk.cz/registry/codelist/EasementTypeValue/EasementAcToDocument"/>
  <cp-ext:geometry>
    <gml:Polygon gml:id="G.EA.24558551010"
        srsName="urn:ogc:def:crs:EPSG::5514" srsDimension="2">
      <gml:exterior>
        <gml:LinearRing>
          <gml:posList>-592554.7 -1150508.98 -592555.31 -1150509.3 -592556.35 -1150509.83
            -592557.07 -1150510.27 -592561.7 -1150513.09 -592561.45 -1150513.52 -592556.75
            -1150510.78 -592556.15 -1150510.43 -592554.43 -1150509.47 -592554.7 -1150508.98
          </gml:posList>
        </gml:LinearRing>
      </gml:exterior>
    </gml:Polygon>
  </cp-ext:geometry>
  <cp-ext:parcel xlink:href="http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp?service=WFS
            &VERSION=2.0.0&request=GetFeature&storedQuery_id=urn:ogc:def:query:OGC-WFS::
            GetFeatureById&Id=CPX.1298200701" />
  <cp-ext:parcel xlink:href="http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp?service=WFS
            &VERSION=2.0.0&request=GetFeature&storedQuery_id=urn:ogc:def:query:OGC-WFS::
            GetFeatureById&Id=CPX.1298220701" />
  <cp-ext:originalGeometryExists>false</cp-ext:originalGeometryExists>
</cp-ext:Easement>
```

4.2.2.6 Geodetic point

Cadastral map contains also several geodetic point fields. As mentioned before, Czech cadastre distinguishes three geodetic point fields that are part of cadastral map: fundamental horizontal control points, minor geodetic control points and associated witness points of horizontal control. For all three types of points was created the same feature type – `GeodeticPoint`. Structure of its type is shown in the Figure 4.19. Complex type `GeodeticPointType` is extension of *`gml:AbstractFeatureType`*.

Points are shown in the map as a single symbol and text label. The text content is stored in the `label` element, representing number of the point within the cadastral zoning and it is portrayed at the coordinates given in the `textPosition` element, together with rotation, size ratio and position reference, as described in 4.2.2.1.

Symbol shall be portrayed at the coordinates given by `geometry` element. Other properties of the geodetic point are stored in the `pointReference` element. Note that it has type with prefix `cuzk` as it is one of the Base types of Czech Office for Surveying, Mapping and Cadastre shown in the Figure 4.11.

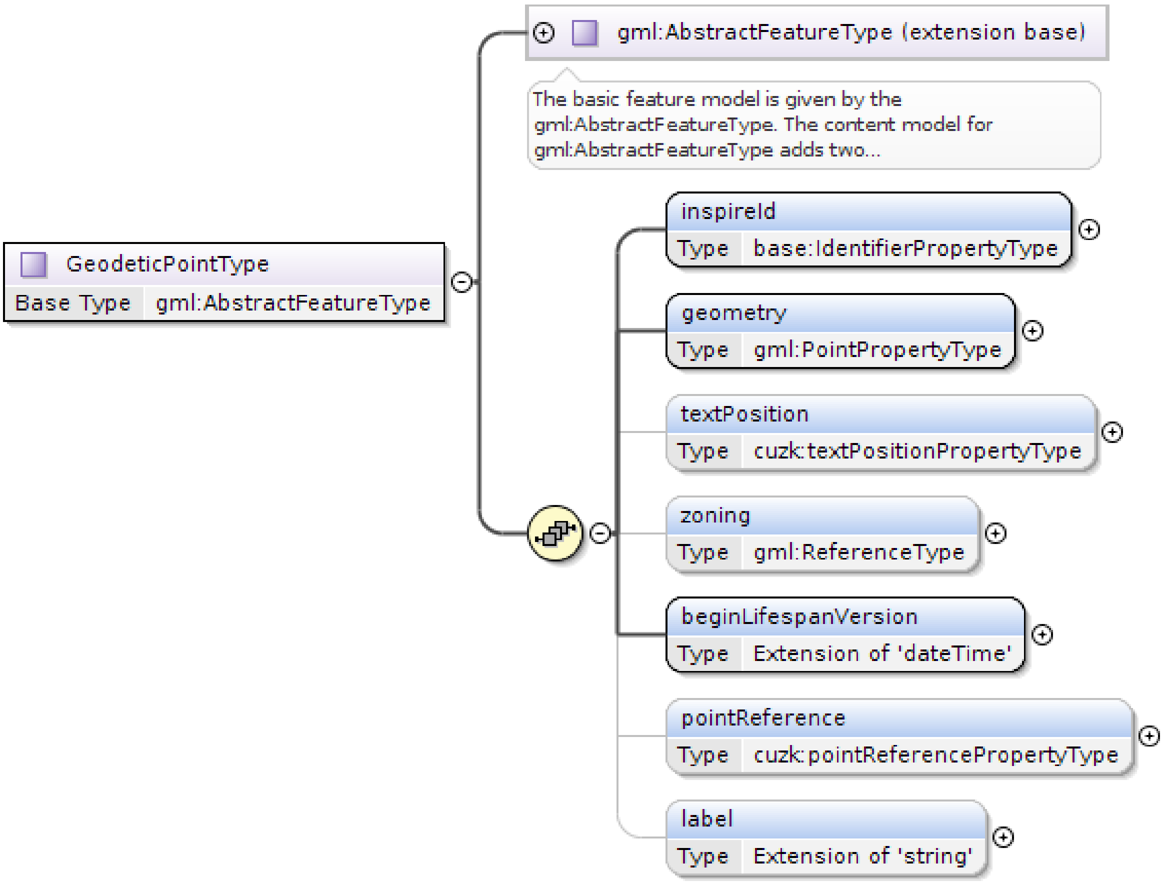


Figure 4.19: Realization of complex type **CadastralParcelsExtended::GeodeticPointType** in XSD shown in oXygen software design view.

Type `pointReferenceType` has three subelements – `pointType`, `pointId` and `pointSymbol`. Element `pointType` references to the type of point field. Its value is from the code list `https://services.cuzk.cz/registry/codelist/PointTypeValue`. Values of `pointType` and `pointId` form unique identifier of the point. Element `pointSymbol` contains `xlink:href` attribute with reference to the point symbol portrayed in a map. It takes one of two valuea from `https://services.cuzk.cz/registry/codelist/GeodeticPointSymbolTypeValue`, labeled geodetic control point and underground geodetic control point. Code list values contain links to the images of the point symbols.

4.2.2.7 Other feature

Feature type ***OtherFeature*** represents all features from the group qcalled Other map features in Cadastral map, as shown in the application schema model in the Figure 4.4. Those feature types have few common attributes and may differ in geometry type. Certain specializations have specific additional attributes. XML schema representation of the main abstract complex type *OtherFeatureType* is shown in the Figure 4.20. It extends `gml:AbstractFeatureType` and defines five basic elements common for all other features: `inspireId`, `zoning`, `type`, `geometry` and `beginLifespanVersion`. Note that `geometry` has no defined type, because type of geometry is specified for specific type of descendants. Possible geometry type representations are `gml:GeometryPropertyType`with ability to represent any GML geometry type, e.g. Point, Curve, Polygon etc., `cuzk:symbolPositionPropertyType` and `cuzk:textPositionPropertyType`. To model this properly in XSD language is used `restriction` instead of `extension`. Where extension allows to add new elements or attributes, restriction specifies allowed values of elements. It is usually used to define strict values of string or integer elements, e.g. limit string to list of values {jan, feb, mar, apr, ...}. In this case it is used to specialize type of `geometry` element.

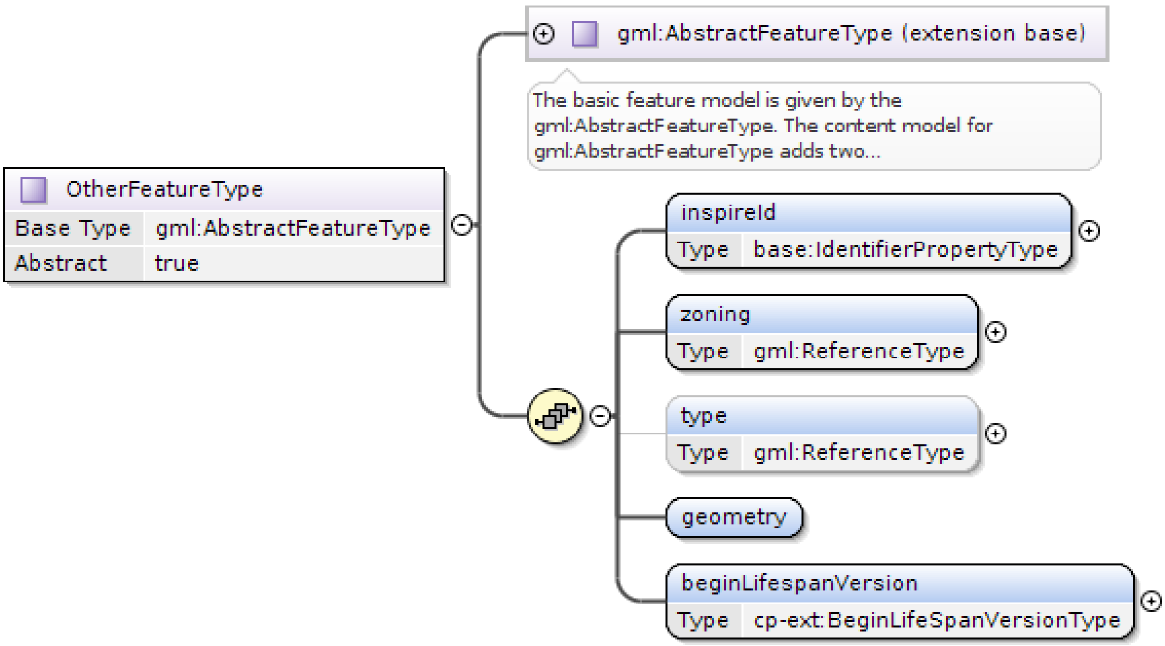


Figure 4.20: Realization of abstract complex type **CadastralParcelsExtended::OtherFeatureType** in XSD shown in oXygen software design view.

Element `type` is a reference to code list `https://services.cuzk.cz/registry/codelist/OtherFeatureTypeValue`. This particular code list has a special attribute for its values specifying exact concrete feature type of other feature. For example, metal mast is kind of planimetry supplement, and so is border mark; church, synagogue or building not registered in SPI are other buildings etc.

Three abstract complex types are created to restrict geometry: *OtherFeatureWGeometryType*, *OtherFeatureWSymbolPositionType* and *OtherFeatureWTextPositionType*. They are still abstract, because they do not represent concrete feature types. They represent features with specific type of geometry. Their descendants are concrete complex types representing specific other features as defined in the application schema.

According to the application schema, complex type shall represent types for feature types **TopographicalName**, **PlanimetrySupplement**, **Building**, **OtherBuilding**, **ProtectedZone** and **InnerDrawing**. Actually, more complex types are needed, because some feature types may have more types of geometry representation.

Complex type for feature type **TopographicalName** is extension of *OtherFeatureWTextPositionT* because it is represented as text. Value of the text is in an additional element `label`. This feature type is used for displaying names of cities, districts, squares, thoroughfares etc.

One of extensions of *OtherFeatureWSymbolPositionType* is `PlanimetrySupplementType` representing other features represented as symbols, such as masts, bridges, border marks etc. Planimetry supplement has no additional elements. Some other planimetry supplements (e.g. overhead line axis or high-voltage and power high-voltage lines) are not be displayed as symbols, but as lines. For such features was created element`PlanimetrySupplementLine` with type `PlanimetrySupplementLineType` extending *OtherFeatureWGeometryType*. This type has additional attributes for original geometry.

Feature types **Building** and **OtherBuilding** are represented through elements with complex types `BuildingType` and `OtherBuildingType`. Those types are extensions of *OtherFeatureWSymbolType* with additional element `building`, referencing to the building from the INSPIRE theme Buildings. Features of the feature type **Building** – unlike **OtherBuilding** – are part of the Set of descriptive information (SPI), a descriptive part of Cadastre of Real Estates. Thus, it may happen that `OtherBuilding` feature has no reference to any building, because it does not have to be included in the INSPIRE theme Buildings. In such cases, `building` element is nilled.

Feture type **ProtectedZone** is represented by element with complex type `ProtectedZoneType`, an extension of *OtherFeatureWGeometryType*. Its geometry is represented as a polygon, hence complex type has additional elements for original geometry. Protected zones features are both natural and historic heritage. Some heritage is represented as a point geometry (e.g. cultural monument). For this case was created complex type `ProtectedZonePointType` as an extension of *OtherFeatureWSymbolPositionType* with no additional attributes.

Feture type **InnerDrawing** represents inner drawings in parcels, such as boundaries of buildings, lawns, walkways etc. They are usually drawn with narrower line. Complex type `InnerDrawingType` is an extension of *OtherFeatureWGeometryType* and has additional elements for original geometry representation.

All other features have similar structure in GML, e.g. `otherBuilding` feature in the following example.

```
<base:member>
  <cp-ext:OtherBuilding gml:id="OB.1336133701">
    <cp-ext:inspireId>
      <base:Identifier>
        <base:localId>OB.1336133701</base:localId>
        <base:namespace>CZ-00025712-CUZK_CPX</base:namespace>
      </base:Identifier>
    </cp-ext:inspireId>
    <cp-ext:zoning
      xlink:href="http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp?service=WFS&
        VERSION=2.0.0&request=GetFeature&storedQuery_id=urn:ogc:def:query:OGC-WFS
        ::GetFeatureById&Id=CZ.600041" />
    <cp-ext:type xlink:href=
        "https://services.cuzk.cz/registry/codelist/OtherFeatureTypeValue/Church"/>
    <cp-ext:geometry>
      <cuzk:symbolPosition>
        <cuzk:geometry>
          <gml:Point gml:id="G.OB.1336133701" srsName="urn:ogc:def:crs:EPSG::5514"
              srsDimension="2">
            <gml:pos>-593518.5 -1149428.57</gml:pos>
          </gml:Point>
        </cuzk:geometry>
        <cuzk:rotation>228</cuzk:rotation>
        <cuzk:sizeRatio uom="ratio">1</cuzk:sizeRatio>
      </cuzk:symbolPosition>
    </cp-ext:geometry>
    <cp-ext:beginLifespanVersion>2011-08-30T09:27:04Z</cp-ext:beginLifespanVersion>
    <cp-ext:building xsi:nil="true" nilReason=
        "http://inspire.ec.europa.eu/codelist/VoidReasonValue/Unpopulated" />
  </cp-ext:OtherBuilding>
</base:member>
```

4.2.2.8 Original geometry

Some of the feature types described in previous sections contain elements refering to the original geometry. Objects of that reference are specific features – extensions of abstract complex type *`OriginalGeometryType`* based on *`gml:AbstractFeatureType`*. Its structure is shown in the Figure 4.21. Extensions of *`OriginalGeometryType`* are divided based on the type of feature of original geometry into types `CadastralParcelOriginalGeometryType`, `CadastralBoundaryOriginalGeometryType`, `EasementOriginalGeometryType`, `PlanimetrySupplementLineOriginalGeometryType`, `InnerDrawingOriginalGeometryType` and `ProtectedZoneOriginalGeometryType`.

Those types extends *`OriginalGeometryType`* by geometry representation in a form of element `geometry` and reference to the belonging feature, i.e. `EasementOriginalGeometryType` has additional element `easement`, which references to the specific `Easement` feature.

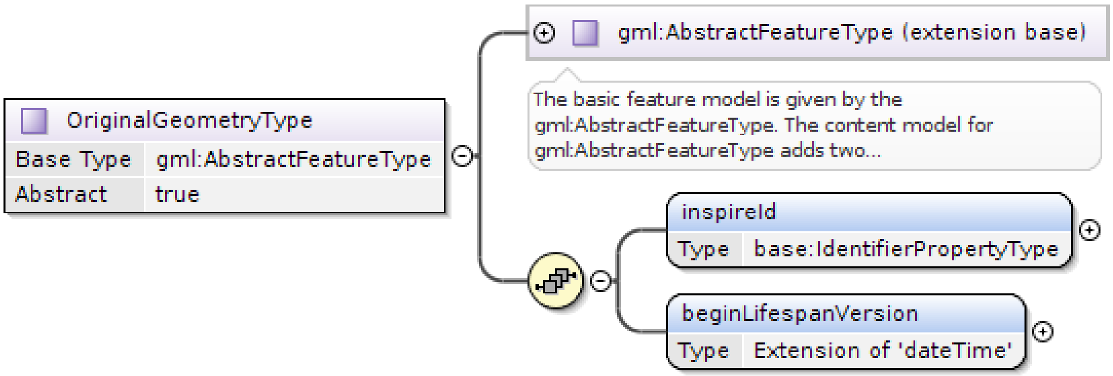


Figure 4.21: Realization of abstract complex type **CadastralParcels-Extended::OriginalGeometryType** in XSD shown in oXygen software design view.

Original geometry is represented in GML as in following example:

```
<base:member>
  <cp-ext:CadastralBoundaryOriginalGeometry gml:id="OG.CBX.60728786">
    <cp-ext:inspireId>
      <base:Identifier>
        <base:localId>OG.CBX.60728786</base:localId>
        <base:namespace>CZ-00025712-CUZK_CPX</base:namespace>
      </base:Identifier>
    </cp-ext:inspireId>
    <cp-ext:beginLifespanVersion>2012-06-14T06:56:31Z</cp-ext:beginLifespanVersion>
    <cp-ext:cadastralBoundary
        xlink:href="http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp?service=WFS&
        VERSION=2.0.0&request=GetFeature&storedQuery_id=urn:ogc:def:query:OGC-WFS
        ::GetFeatureById&Id=CBX.60728786" />
    <cp-ext:geometry>
      <gml:Curve gml:id="OLG.CBX.60728786" srsName="urn:ogc:def:crs:EPSG::5514"
          srsDimension="2">
        <gml:segments>
          <gml:ArcString numArc="1">
            <gml:coordinates>
              -592775.25,-1150660.14 -592776.28,-1150662.55 -592778.06,-1150664.58
            </gml:coordinates>
          </gml:ArcString>
        </gml:segments>
      </gml:Curve>
    </cp-ext:geometry>
  </cp-ext:CadastralBoundaryOriginalGeometry>
</base:member>
```

Types of original geometry are described in the Section 4.2.2.1, where is first described referencing to the `originalGeometry` features. Visualization of original geometry in two examples is in the Figure 4.22.

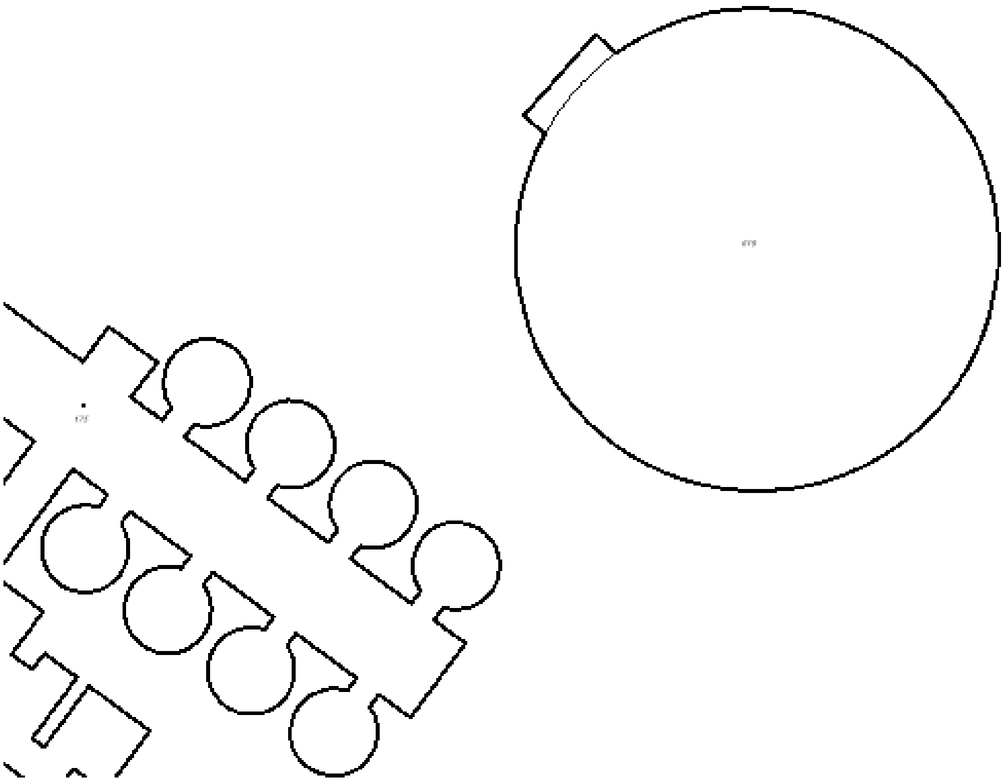


Figure 4.22: Example of original geometry in a form of arc segments and circle.

4.2.2.9 Cadastral Parcels Extended XML Schema evaluation

Only one XSD file had to be created in order to implement newly created application schema Cadastral Parcels Extended. Another one is for set of specific types from the environment of Czech cadastre. Both XSD files are published at the web of Czech Office for Surveying, Mapping and Cadastre. Code list register with a set of basic code lists specific for extension of Cadastral Parcels was also created.

The Czech national extension of INSPIRE theme Cadastral Parcels aims on enhancing content of the INSPIRE theme Cadastral Parcels in a way of better usage by national users. On the other hand, it takes all advantages given by INSPIRE standardization, including open format supported by most GIS software.

National extension focuses on usability, including proper portrayal of features as defined in the Annex of Cadastral Decree no. 357/2013 Sb. Code list register contains links to image files, that shall be used for portraying features. XML Schema also allows to keep information about rotation and size ratio of texts and symbols, althought additional knowledge may be sometimes needed (e.g. for arrow geometry).

Thanks to the extensive character of data set it does not really matter which kind of user wants to use the data. All basic information needed by INSPIRE are present and usable. National user used to process all additional information valid to the Czech cadastre will find it there, including the portrayal rules.

4.3 Transformation and mapping of data

Application schemas show the content of data, XSD files represent exact models of data itself as they are published. Moreover, it is possible to validate data against XSD to easily check if data files correspond to schema. Data itself are stored in source databases. Transformation process consists of several steps, as mentioned in the introduction to this Chapter 4. These steps are described in detail in further sections.

In the Section 4.3.1 is described creation of tables and views in the Publication database. Views shall contain information in the form that is used in GML data, hence this section describes mostly mapping between the data as it is stored in the ISKN and ISÚI databases and INSPIRE model.

In the Section 4.3.2 is described technical process of creating GML data from the publication database.

4.3.1 Publication database, tables and views

Publication database was originally created as a source for publishing data of Cadastral map. It was created with several rules:

- it contains only up–to–date data,
- structure of data corresponds to the publication,
- it is never updated directly, but from ISKN and ISÚI databases.

Publication database is used as a source for Map server of the Czech Office for Surveying, Mapping and Cadastre. Data from Publication database are provided through various services, such as Web Map Service (WMS), Web Feature Service (WFS) etc., as well as pre–defined files, that are also generated indirectly from Publication database.

Tables and views for the purpose of INSPIRE theme Cadastral Parcels are already present in the publication database. Extension of this INSPIRE theme reuses those tables and views.

INSPIRE theme Buildings uses data from both ISKN and ISÚI databases. From the source databases, data are transformed into two separate tables (one for each source database) and then aggregated into the views. Database view representing buildings puts together information from both source databases.

4.3.1.1 Implementation of the theme Buildings in Publication database

It is important to understand that building information comes from two sources:

- Database ISKN contains information about buildings as they are defined by the Cadastral Law no. 256/2013 Sb.,
- database ISÚI contains information about buildings (construction objects) as they are defined by the Law no. 111/2009 Sb., about Register of Territorial Identification and Real Estate.

Both databases keep different information about buildings. Moreover, buildings from one database does not neccessarily have to be present in the other one. In simple terms, ISKN keeps information about geometry and connection of buildings to cadastral parcels and zonings and ISÚI keeps information about technical–economical attributes, such as number of floors, number of flats, type of construction, connection to power networks etc. Content of source databases is described in more detail in the Section 3.3.1.

INSPIRE theme Buildings also describes building parts. As a source of building parts are considered entrances in the of IS'UI database as described in the Section 3.3.1. Entrances, as points with attached technical–economical attributes, are present only if building from ISÚI database have more than one. Otherwise, all attributes that shall belong to entrance are direct attributes of building itself. All this information is stored in ISÚI database.

The original idea how to gather all the information in the Publication database (in the Figure 4.23) consists in creating one table for buildings from ISKN, one table for buildings from ISÚI and one new table aggregating both tables. This table is called PUB_MUSTEK (PUB stands for publication and MUSTEK means bridge in Czech) and contains three attributes:

- `MUSTEK_ID` – generated identifier of database object,
- `SO_KOD` – identifier of construction object from ISÚI,
- `BUD_ID` – identifier of building from ISKN.

Publication database also contains new table PUB_VCHODY with information about entrances. Publication database uses foreign keys to link data from both databases together. Buildings in ISKN are associated with Parcels and buildings in ISÚI have association links to Addresses.

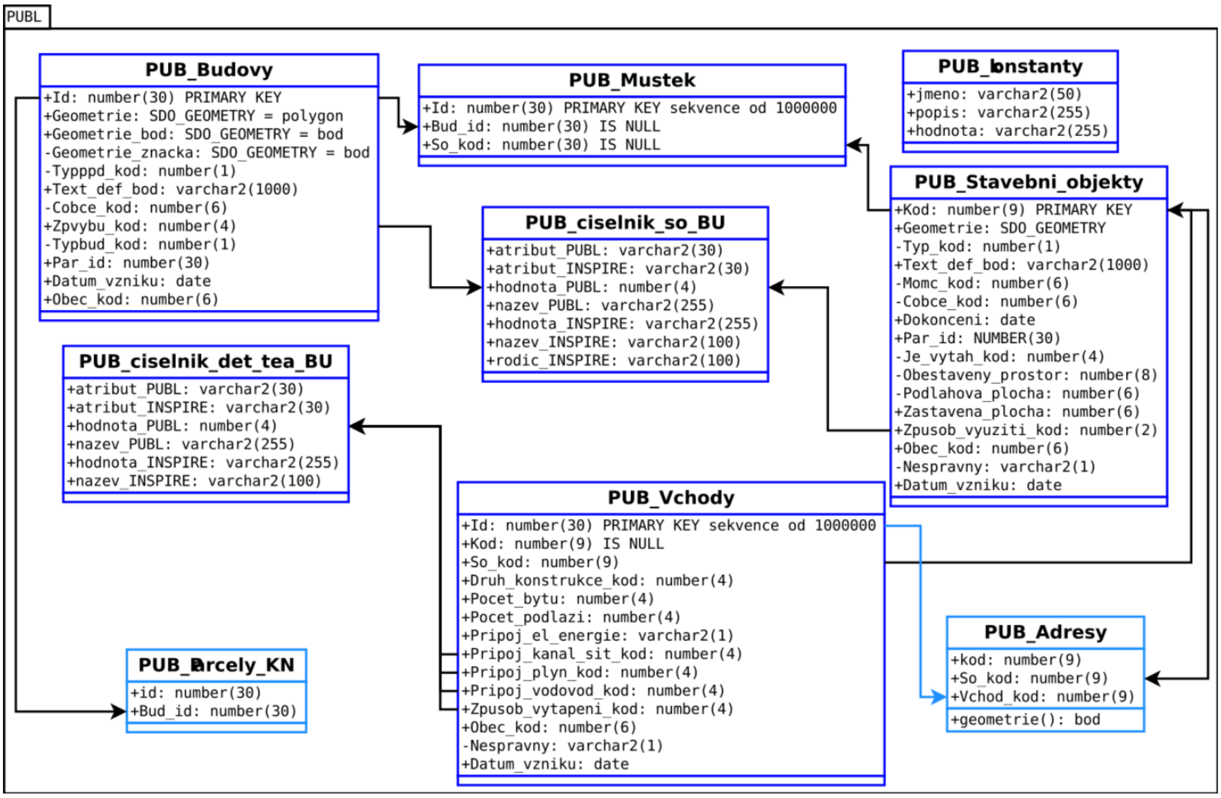


Figure 4.23: Original design of tables in Publication database used for implementation of INSPIRE theme Buildings.

Original source databases have defined own code lists, while INSPIRE expects usage of INSPIRE code list values. Mapping of source database values into INSPIRE code lists was done through new mapping tables in Publication database. In the Table 4.1 is example of such mapping (names are translated and original table also contains link to INSPIRE code list register).

PUBL attribute	INSPIRE attribute	PUBL value	INSPIRE value name
`zpvybu_kod`	currentUse	industrial building	industrial
`zpvybu_kod`	currentUse	farmhouse	agriculture

Table 4.1: Example of mapping table between values used in source databases and INSPIRE code lists.

Views in Publication database are used to get all data of one feature type in one place. For the implementation of theme Buildings are created two views – `PUB_SO_BUD_GMLI` and `PUB_VCHODY_GMLI`. First represents feature type **Building**, the second **BuildingPart**.

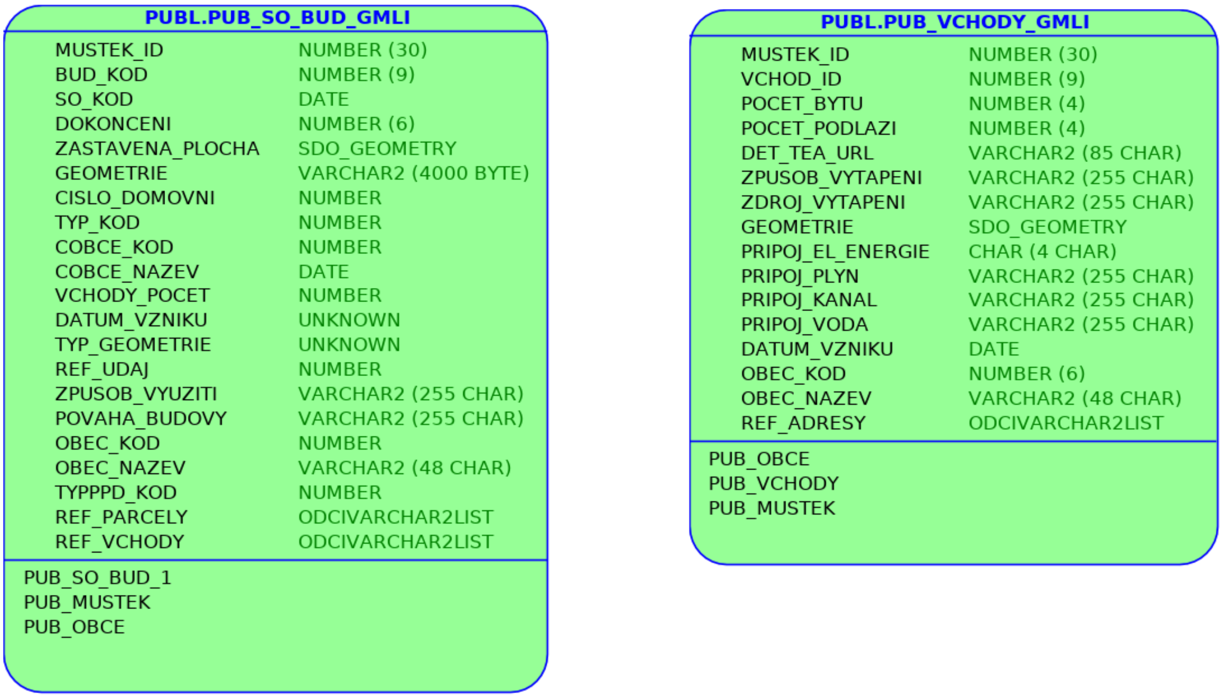


Figure 4.24: Views in Publication database representing feature types **Building** (`PUB_SO_BUD_GMLI`) and **BuildingPart** (`PUB_VCHODY_GMLI`).

Schema of both views is in the Figure 4.24. Values in the views are in the form that is used in the GML output, e.g. code list values from INSPIRE are used instead of values from ISKN or ISÚI code lists. Creation of GML data is described in the section 4.3.2.

4.3.1.2 Implementation of the theme Cadastral Parcels Extended in Publication database

Cadastral Parcels Extended is extension of theme that was already implemented in the Czech Office for Surveying, Mapping and Cadastre. Therefore Publication database already contains tables and views for some feature types. Extended feature types only reuses the existing tables and views, enriching it by newly used attributes.

Application schema for Cadastral Parcels Extended was created based on the content of ISKN database. New feature types content is based just on the content of ISKN tables. Tables in Publication database are basically up–to–date version of tables from ISKN.

Difference between tables and views is mostly in the mapping between values of ISKN code lists into new code lists created in the registry of code lists of Czech Office for Sur-

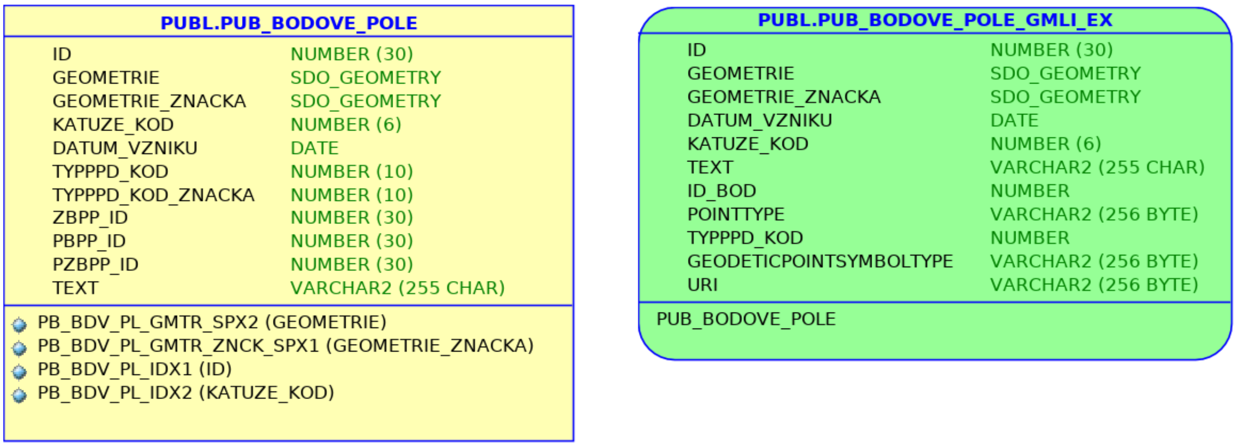


Figure 4.25: Table `PUB_BODOVE_POLE` and view `PUB_BODOVE_POLE_GMLI_EX` in Publication database representing feature type **GeodeticPoint** show that only difference is mapping of values into the form expected by the XML Schema for Cadastral Parcels Extended.

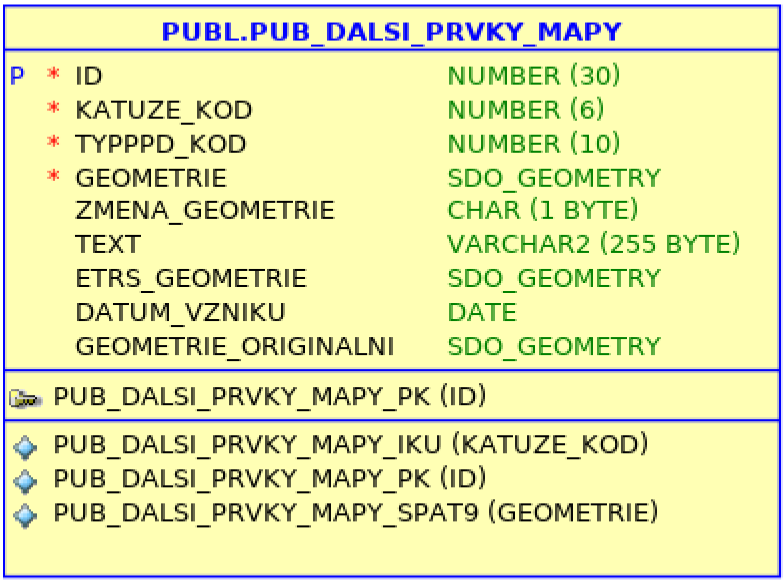


Figure 4.26: Database table `PUB_DALSI_PRVKY_MAPY` contains data representing feature type ***OtherFeature***. It is transformed into more views, based on the concrete extension of abstract feature type according to the value of the attribute `TYPPPD_KOD`. Views are in the Figure 4.27.

veying, Mapping and Cadastre. Nice example of this case is table and view with data for feature type **GeodeticPoint**. Both table and view are in the Figure 4.25.

Figure 4.27: Database views representing all specializations of abstract feature type ***OtherFeature***.

There are few exceptions to this rule. All data for all extensions of feature type ***OtherFeature*** are stored in one table, but for every concrete extension exists standalone view. Database table shown in the Figure 4.26 is a source for all views that are visible in the Figure 4.27. Based on the value of the TYPPPD_KOD attribute, data are transformed into one of those views.

4.3.2 Creation of GML data

For the transformation of data from databases into publication formats (GML for INSPIRE data, but data may be published in other formats, e.g. DGN, DXF, Shapefile or VFK[7], which is format used by Czech Office for Surveying, Mapping and Cadastre for publication of cadastral data) and for providing data using web services is used third party solution Marushka® by the company Geovap. This software is used at the Czech Office for Surveying, Mapping and Cadastre since 2010 for publication of INSPIRE data and services and its developers reflects the needs of their customers during the development of this software.

Transformation of data is done in two ways. Direct transformation and transformation into WKB files. WKB files are used in the queries selected by bounding box (both WMS and WFS service). Queries selecting data based on identifiers access database directly. Both ways transform data from the Publication database into the GML structure. The whole solution is a black box, while Czech Office for Surveying, Mapping and Cadastre delivers database and desired output in the form of sample GML files. In cooperation with data modeler from the Office Geovap created functional mapping of Publication database data into GML structure in a few steps.

In the next step are output GML files checked by data modeler. He ususally requests certain data to check possible problems. Afterwords he sends feedback to the Geovap and the process is repeated until there are no issues unsloved.

Data are provided in two ways – as a pre–defined files or directly. Pre–defined files are generated per cadastral zoning in case of Cadastral Parcels Extended and per municipality in case of Buildings. Possible changes in pre–defined files are checked daily. If something in the file changes, the whole file is generated again to be kept up-to-date.

Direct access allows service to access directly Publication database and transform data into GML on the fly. Servicee query is translated into SQL query and result is transformed into GML, which is then returned to the service. For the queries selecting data based on the bounding box are used WKB files, containing parts of database. Files are accessed instead of accessing database directly, which would be slower.

4.4 Modeling, mapping and transformation evaluation

Outputs of analysis written in the Section 3.4 has set up few goals. In this Chapter, most of them are accomplished.

[7] VFK files are generated directly from ISKN database.

Application schema for Cadastral Parcels Extended was created based on the existing application schema for Cadastral Parcels with respect to the content of Cadastral map. Similarly, technical realization of the application schema was based on the XML Schema for Cadastral Parcels.

Application schemas for Buildings already exists, but XML Schemas for Buildings extended base and Buildings extended 2D were created as part of thist dissertation thesis.

Data are published from the Publication database, which contains only up-to-date data in a form designed for publication. For both described themes were created database tables, containing relevant data in a form given by the source database, and database views shaping those data into the form for publication. Those data are then transformed into GML by the software Marushka®.

Data are transformed from Publication database into GML in order to be published. Publication of data is the topic of the following Chapter 5.

Chapter 5

Publication

Publication of INSPIRE data is governed by two legislation documents for INSPIRE Network Services: Commission Regulation (EC) No 976/2009 from 19th October 2009 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the Network Services[1] and Commission Regulation amending Regulation (EC) No 976/2009 as regards download services and transformation service[2] and non–binding Technical Guidelines specifying implementation of technical obligations.

Technical Guidelines focus on specific types of Network services shown in the Figure 2.3. For the publication of specific INSPIRE data for themes Buildings and Cadastral Parcels Extended are crucial View Services (providing map images) and Download Services (providing data in GML). Both data and services shall be described by metadata. Metadata creation for data is done in the same way as for Administrative Units and Addresses described in [5]. Metadata are created according to the INSPIRE Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119 [28].

5.1 Download services

As shown in the Figure 2.3, download service allows user to get vector data, e.g. in GML format. Technical Guidance on Download Services describes three ways of publishing data:

- Direct access using Web Feature Service 2.0.0,
- pre–defined files using Web Feature Service 2.0.0 stored queries,
- pre–defined files using Atom service.

According to the Table 14 in Technical Guidance for the implementation of INSPIRE Download Services [29] is at least one way of implementing pre–defined mandatory. The

[1] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009R0976

[2] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:02009R0976-20101228

rest is optional. Both INSPIRE Cadastral Parcels Extended and INSPIRE Buildings support all three options for downloading data.

Pre–defined files have unique identifier consisting of theme namespace and local identifier of a territorial unit, to which data belongs. For Buildings, identifier may look like this:

```
<base:Identifier>
  <base:localId>BU.SD.544256</base:localId>
  <base:namespace>CZ-00025712-CUZK_BU</base:namespace>
</base:Identifier>
```

and for Cadastral Parcels Extended like this:

```
<base:Identifier>
  <base:localId>CPX.SD.600041</base:localId>
  <base:namespace>CZ-00025712-CUZK_CPX</base:namespace>
</base:Identifier>
```

Letters `SD` in `localId` stands for Spatial Dataset and `namespace` consists of country code, provider organization identification number and its name (CUZK is short for Český úřad zeměměřický a akatastrální – Czech Office for Surveying, Mapping and Cadastre). This form of identifier was agreed on Technical Working Group on Metadata in the early phase of INSPIRE implementation in the Czech Republic. New version of Technical Guidelines on Metadata in version 2.0 defines identifiers in the form of IRI. Identifiers in the data, metadata and services are interconnected, thus change of identifiers requires huge changes in infrastrucutre of all INSPIRE data in the Czech Republic.

Note that the identifier identifies a file containing data of the territorial unit, not identifier of that unit itself. There is no link to the file from features published via direct access, only link to the territorial unit. The identifier serves to distinguish various files and it shall be mentioned in the GetCapabilities document of WFS service. According to the Implementing Rules are pre–defined files treated as data sets and every data set shall have its own metadata record (in the meaning of ISO 19115) and its own service end–point. In the case of Buildings that means 6 246 metadata records and service end–points as well as 6 246 additional rows in the GetCapabilities document with links to the data (and a little bit less than 13 000 in the case of Cadastral Parcels). Publishing data through various service end–points does not make much sense, because the same end–point is used for direct access where it is completely legal to request data from more than one data set. The data of the whole theme aggregating all data sets are treated as data set series. According to the Implementing Rules it is correct to have a metadata record for data set series, but service end–point must be provided per data set.

The solution, however not yet implemented, is to treat data of the whole theme in the Czech Republic as a single data set and all data provided as pre–defined files treat as subsets of this data set. Then all data would be published by the end–point of one data set. Moreover, direct access requests for all data are points to one data set. The demonstrated solution requires automated generating of data set metadata from the database, which is prepared for publication by the Czech Office for Surveying, Mapping and Cadastre.

5.1.1 Direct access service via WFS 2.0.0

Usage of WFS service as the INSPIRE Download Service is described in the Chapter 7 of Technical Guidance for the implementation of INSPIRE Download Services[30]. Web Feature Service in the required version 2.0.0 is described in the OpenGIS Web Feature Service 2.0 Interface Standard [29], reusing the ISO 19142.

Capabilites of the service are described in the GetCapabilities document, which is metadata file of the service returned as the result of WFS service `getCapabilities` operation. Using a Key Value Pair (KVP) method, `getCapabilites` request has following structure:

```
{service_endpoint}?service=WFS&version=2.0.0&request=GetCapabilities
```

String `service_endpoint` is replaced by the address of the service. For the theme Buildings is address of the service `http://services.cuzk.cz/wfs/inspire-bu-wfs.asp` and for Cadastral Parcels Extended `http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp`. The `getCapabilties` request response corresponds to the chapter 8 of [29].

Operation `GetFeature` for direct access has following basic structure in KVP:

```
{service_endpoint}?service=WFS&version=2.0.0&request=GetFeature
```

Additional parameters for `GetFeature` operation according to ad hoc query keywords from [29] are:

- `typenames` – only mandatory parameter, defines feature type name(s) of desired output,
- `bbox` – specify the area of request,
- `resourceId` – specifies the identifier of desired resource,
- `srsName` – specifies coordinate reference system,
- `filter`, `filter_language` – allows additional filters based on ISO 19143,
- `aliases` – defines usage of aliases in output,
- `sortBy` – specifies a list of property names whose values are used for sorting output features.

Standard presentation parameters of the `GetFeature` operation are:

- `startindex` – indicates index of the result set to start presenting results (default value is 1),

- `count` – limits number of requested values of a query response,
- `outputFormat` – defines format used to encode response resources (default value is "application/gml+xml; version=3.2"),
- `resultType` – determines one of the two ways of output representation, default value is "results", returning features including all desired information; second way is hits, returning only number of corresponding results.

Detailed description of WFS service is not goal of this dissertation thesis. For more information look into the OGC standard.

The Section is closed by the example of a direct access WFS query and its (shortened output.

```
http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp
    ?service=WFS
    &version=2.0.0
    &request=GetFeature
    &typenames=CadastralBoundary
    &srsName=urn:ogc:def:crs:EPSG::5514
    &featureId=CBX.7512647
```


```
<?xml version="1.0" encoding="utf-8"?>
<!--Generated by Marushka, version 4.2.9.3, GEOVAP, spol. s r.o., 01.12.2019.-->
<FeatureCollection xmlns:xsd="http://www.w3.org/2001/XMLSchema"
             xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
             xmlns:base="http://inspire.ec.europa.eu/schemas/base/3.3"
             xmlns:xlink="http://www.w3.org/1999/xlink"
             xmlns:cp-ext="http://services.cuzk.cz/xsd/inspire/cp-ext/4.0"
             xmlns:gmd="http://www.isotc211.org/2005/gmd"
             xmlns:gco="http://www.isotc211.org/2005/gco"
             xmlns:cp="http://inspire.ec.europa.eu/schemas/cp/4.0"
             xmlns:cuzk="http://services.cuzk.cz/xsd/inspire/cuzkTypes/1.0"
             xmlns:gn="http://inspire.ec.europa.eu/schemas/gn/4.0"
             xmlns:gml="http://www.opengis.net/gml/3.2"
             xsi:schemaLocation="[...]"
             timeStamp="2019-12-01T14:08:22" numberMatched="1" numberReturned="1"
             xmlns="http://www.opengis.net/wfs/2.0">
  <boundedBy>
    <gml:Envelope srsName="urn:ogc:def:crs:EPSG::5514" srsDimension="2">
      <gml:lowerCorner>-750816.86 -1136777.35</gml:lowerCorner>
      <gml:upperCorner>-750789.56 -1136753.66</gml:upperCorner>
    </gml:Envelope>
  </boundedBy>
  <member>
    <cp-ext:CadastralBoundary gml:id="CBX.7512647">
      <cp:beginLifespanVersion>2011-08-26T09:03:49Z</cp:beginLifespanVersion>
      <cp:endLifespanVersion xsi:nil="true"
          nilReason="http://inspire.ec.europa.eu/codelist/VoidReasonValue/Unpopulated" />
```

```
      <cp:estimatedAccuracy uom="m">0.14</cp:estimatedAccuracy>
      <cp:geometry>
        <gml:Curve gml:id="C.CBX.7512647"
          srsName="urn:ogc:def:crs:EPSG::5514" srsDimension="2">
          <gml:segments>
            <gml:LineStringSegment>
              <gml:posList>
                [...]
              </gml:posList>
            </gml:LineStringSegment>
          </gml:segments>
        </gml:Curve>
      </cp:geometry>
      <cp:inspireId>
        <base:Identifier>
          <base:localId>CBX.7512647</base:localId>
          <base:namespace>CZ-00025712-CUZK_CPX</base:namespace>
        </base:Identifier>
      </cp:inspireId>
      <cp:validFrom xsi:nil="true"
          nilReason="http://inspire.ec.europa.eu/codelist/VoidReasonValue/Unknown" />
      <cp:parcel xlink:type="simple"
          xlink:href="http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp?[...]"
          xlink:title="CPX.2452473308" />
      <cp:parcel xlink:type="simple"
          xlink:href="http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp?[...]"
          xlink:title="CPX.3105202308" />
      <cp-ext:boundaryType
          xlink:href="https://services.cuzk.cz/registry/codelist/BoundaryTypeValue/
          CadastralParcelsBoundaryStandard" />
      <cp-ext:originalGeometryExists>false</cp-ext:originalGeometryExists>
    </cp-ext:CadastralBoundary>
  </member>
</FeatureCollection>
```


5.1.2 Pre–defined files via WFS 2.0.0 stored queries

Downloading pre–defined files via WFS 2.0.0 is described in Chapter 6 of Technical Guidance for the implementation of INSPIRE Download Services[30]. It defines stored query `http://inspire.ec.europa.eu/operation/download/GetSpatialDataSet`[3] with following parameters:

- `CRS`,
- `DataSetIdCode`,
- `DataSetIdNamespace` and

[3]There are two same stored queries implemented in Marushka. Title of the second one, with the same functionality, is short `GetSpatialDataSet`.

- Language.

Values of parameters DataSetIdCode and DataSetIdNamespace are the same as localId and namespace from metadata records shown in the beginning of the Section 5.1. Parameter CRS contains information about Coordinate reference system in a form of EPSG code. All pre–defined files are generated in coordinate reference systems with EPSG codes 5514 and 4258[4]. Only these two CRS may be used as the value of the stored query parameter. Parameter Language contains three letters country code according to the ISO 3166 standard.

The implementation of the service for the needs of Czech Office for Surveying, Mapping and Cadastre was doen in Marushka® by Geovap. The request expects one additional parameter zipped with possible values true or false. The value of this parameter specifies if the response to the query is a zipped archive or a GML file. Pre–defined files may be quite large and zipped form may be much smaller, e.g. pre–defined file for the cadastral unit Aš containing data of theme Cadastral Parcels Extended has 4.1 MB as zipped archive and 110.5 MB as a GML file.

Example of a WFS service request returning pre–defined file for the cadastral unit Aš in the czech language using GML format:

```
http://services.cuzk.cz/wfs/inspire-cpx-wfs.asp
        ?service=wfs
        &version=2.0.0
        &request=getFeature
        &storedQuery_id=GetSpatialDataSet
        &CRS=urn:ogc:def:crs:EPSG::5514
        &DataSetIdCode=CPX.SD.668591
        &DataSetIdNamespace=CZ-00025712-CUZK_CP
        &language=cze
        &zipped=false
```

5.1.3 Pre–defined files via Atom

Other way of downloading pre–defined files is via Atom service. According to the Chapter 5 of Technical Guidance for the implementation of INSPIRE Download Services [29], Atom service shall follow Atom syndication format. Atom has two level of feeds. Top level Service feed is a metadata record describing the service with multiple entry elements containing information about single data sets, including links to Dataset feeds. The following snippet shows a Service feed for the theme Buildings with two entries.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<feed xmlns="http://www.w3.org/2005/Atom"
      xmlns:georss="http://www.georss.org/georss"
      xmlns:inspire_dls="http://inspire.ec.europa.eu/schemas/inspire_dls/1.0"
```

[4]More information about the reference systems can be found at http://epsg.io/5514 and http://epsg.io/4258

```
    xmlns:opensearch="http://a9.com/-/spec/opensearch/1.1/"
    xml:lang="cs">
<id>http://atom.cuzk.cz/BU/BU.xml</id>
<title>Download service Atom for INSPIRE Buildings in the Czech Republic</title>
<subtitle>Download service for Buildings is public download service providing
      data from the Information system of the Real Estates and Inofrmation system
      of the Terrestrial identification. It allows multiple repeating downloads
      of datain the form of files provided per municipalities using the Atom
      technology. Download service provides harmonized data of the INSPIRE theme
      Buildings in the GML format according to the application schema Buildings
      Extended 2D. Service filfils all technical guidance for INSPIRE download
      services in the version 3.1.
</subtitle>
<updated>2019-11-23T07:21:15+01:00</updated>
<author>
    <name>Czech Office for Surveying, Mapping and Cadastre</name>
    <uri>http://geoportal.cuzk.cz</uri>
    <email>cuzk.helpdesk@cuzk.cz</email>
</author>
<rights>Data are provided without fees or other constraints.</rights>
<link href="http://geoportal.cuzk.cz/getHTML.aspx?mode=Metadata&fnc=getRecord
      &identifierid=CZ-CUZK-ATOM-BU" rel="describedby"
      title="download service metadata" type="application/vnd.iso.19139+xml"/>
<link href="http://atom.cuzk.cz/BU/OSD-BU.xml" hreflang="cs" rel="search"
      title="CUZK-Atom-BU" type="application/opensearchdescription+xml"/>
<link href="http://atom.cuzk.cz/BU/BU.xml" hreflang="cs" rel="self"
      type="application/atom+xml"/>
<entry>
    <id>http://atom.cuzk.cz/BU/datasetFeeds/CZ-00025712-CUZK_BU_500011.xml</id>
    <title>
        INSPIRE - Buildings - Municipality - Zelechovice nad Drevnici [500011]
    </title>
    <updated>2019-11-16T04:17:32+01:00</updated>
    <author>
        <name>Czech Office for Surveying, Mapping and Cadastre</name>
        <uri>http://geoportal.cuzk.cz</uri>
        <email>cuzk.helpdesk@cuzk.cz</email>
    </author>
    <rights>Data are provided without fees or other constraints.</rights>
    <link href="http://atom.cuzk.cz/BU/datasetMetadata/CZ-00025712-CUZK_BU_500011_M.xml"
          rel="describedby" title="dataset metadata" type="application/xml"/>
    <link href="http://atom.cuzk.cz/BU/datasetFeeds/CZ-00025712-CUZK_BU_500011.xml"
          rel="alternate" title="dataset feed" type="application/atom+xml"/>
    <category label="S-JTSK" term="http://www.opengis.net/def/crs/EPSG/0/5514"/>
    <category label="ETRS89" term="http://www.opengis.net/def/crs/EPSG/0/4258"/>
    <inspire_dls:spatial_dataset_identifier_code>
          CZ-00025712-CUZK_BU_500011
    </inspire_dls:spatial_dataset_identifier_code>
    <inspire_dls:spatial_dataset_identifier_namespace>
          CUZK
      </inspire_dls:spatial_dataset_identifier_namespace>
```

```
      <georss:polygon>49.2264 17.77 49.2221 17.6984
            49.1697 17.7059 49.1741 17.7774 49.2264 17.77
      </georss:polygon>
  </entry>
  <entry>
      <id>http://atom.cuzk.cz/BU/datasetFeeds/CZ-00025712-CUZK_BU_500020.xml</id>
      <title>INSPIRE - Buildings - Municipality - Petrov nad Desnou [500020]</title>
      <updated>2019-11-19T00:16:48+01:00</updated>
      <author>
          <name>Czech Office for Surveying, Mapping and Cadastre</name>
          <uri>http://geoportal.cuzk.cz</uri>
          <email>cuzk.helpdesk@cuzk.cz</email>
      </author>
      <rights>Data are provided without fees or other constraints.</rights>
      <link href="http://atom.cuzk.cz/BU/datasetMetadata/CZ-00025712-CUZK_BU_500020_M.xml"
            rel="describedby" title="dataset metadata" type="application/xml"/>
      <link href="http://atom.cuzk.cz/BU/datasetFeeds/CZ-00025712-CUZK_BU_500020.xml"
            rel="alternate" title="dataset feed" type="application/atom+xml"/>
      <category label="S-JTSK" term="http://www.opengis.net/def/crs/EPSG/0/5514"/>
      <category label="ETRS89" term="http://www.opengis.net/def/crs/EPSG/0/4258"/>
      <inspire_dls:spatial_dataset_identifier_code>
            CZ-00025712-CUZK_BU_500020
      </inspire_dls:spatial_dataset_identifier_code>
      <inspire_dls:spatial_dataset_identifier_namespace>
            CUZK
      </inspire_dls:spatial_dataset_identifier_namespace>
      <georss:polygon>50.029 17.0797 50.0248 17.0171
            49.9823 17.0239 49.9864 17.0864 50.029 17.0797
      </georss:polygon>
  </entry>
</feed>
```

The feed contains basic information about the service including link to the ISO Metadata document in the element `link` with `rel="describedBy"` attribute and link to the opensearch document for the service in the element `link` with `rel="search"` attribute.

Each `entry` has specific identifier, title, date of last update and other metadata elements and also few `link` elements. The one with `rel="describedBy"` attribute contains link to the data set metadata, the one with `rel="alternate"` attribute contains link to the Dataset feed. Note that it is the same uri as identifier. Each entry has several `category` elements, specifying coordinate reference system in which are pre–defined files available. The Dataset feed for the municipality Petrov nad Desnou follows.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<feed xmlns="http://www.w3.org/2005/Atom"
      xmlns:georss="http://www.georss.org/georss"
      xmlns:inspire_dls="http://inspire.ec.europa.eu/schemas/inspire_dls/1.0"
      xmlns:opensearch="http://a9.com/-/spec/opensearch/1.1/"
      xml:lang="cs">
    <id>http://atom.cuzk.cz/BU/datasetFeeds/CZ-00025712-CUZK_BU_500020.xml</id>
    <title>INSPIRE - Buildings - Municipality - Petrov nad Desnou [500020]</title>
```

```
    <updated>2019-11-19T00:16:48+01:00</updated>
    <author>
        <name>Czech Office for Surveying, Mapping and Cadastre</name>
        <uri>http://geoportal.cuzk.cz</uri>
        <email>cuzk.helpdesk@cuzk.cz</email>
    </author>
    <rights>Data are provided without fees or other constraints.</rights>
    <link href="http://atom.cuzk.cz/BU/BU.xml" hreflang="cs" rel="up"
          type="application/atom+xml"/>
    <link href="http://inspire.ec.europa.eu/applicationschema/bu/" hreflang="cs"
          rel="describedby" type="text/html"/>
    <entry>
        <id>http://services.cuzk.cz/gml/inspire/bu/epsg-5514/500020.zip</id>
        <title>Petrov nad Desnou [500020] S-JTSK</title>
        <updated>2019-11-18T22:58:01+01:00</updated>
        <link href="http://services.cuzk.cz/gml/inspire/bu/epsg-5514/500020.zip"
          length="151963" rel="alternate" type="application/x-gmz"/>
        <category label="S-JTSK" term="http://www.opengis.net/def/crs/EPSG/0/5514"/>
    </entry>
    <entry>
        <id>http://services.cuzk.cz/gml/inspire/bu/epsg-4258/500020.zip</id>
        <title>Petrov nad Desnou [500020] ETRS89</title>
        <updated>2019-11-18T22:58:02+01:00</updated>
        <link href="http://services.cuzk.cz/gml/inspire/bu/epsg-4258/500020.zip"
          length="147063" rel="alternate" type="application/x-gmz"/>
        <category label="ETRS89" term="http://www.opengis.net/def/crs/EPSG/0/4258"/>
    </entry>
</feed>
```

Dataset feed has similar structure as Service feed. Besides basic data set information it contains two `link` elements and two `entry` elements. One link points to the parent Service feed, the other one to the application schema of the data included in the data set. Entries correspond to the distributions of the data set. In the case of INSPIRE Atom service implemented on the Czech Office for Surveying, Mapping and Cadastre, every coordinate reference system has its distribution. Implementation of ATOM service by Czech Office for Surveying, Mapping and Cadastre provides only zipped files.

This version of Atom service was implemented by Jaromír Rokusek as his master thesis[31]. It has some bugs, but main problem of the implementation is that the whole program has to be recompliled after editing, which does not allow simple adding of new themes. New version of Atom service is in progress as a part of software Marushka® by Geovap. Geovaps main task is implementation of the service, while XML files representing feeds are generated from the Publication database at the Czech Office for Surveying, Mapping and Cadastre. Content of the feeds is not changed, but data are generated automatically. That relates to the preparation of generating metadata for single dat sets.

5.1.4 Performance requirements of download services

In the INSPIRE Implementing Rules is performance of a service defined as:

"For the Get Download Service Metadata operation, the response time for sending the initial response shall be maximum 10 seconds in normal situation.

For the Get Spatial Data Set operation and for the Get Spatial Object operation, and for a query consisting exclusively of a bounding box, the response time for sending the initial response shall be maximum 30 seconds in normal situation then, and still in normal situation, the download service shall maintain a sustained response greater than 0,5 Megabytes per second or greater than 500 Spatial Objects per second.

For the Describe Spatial Data Set operation and for the Describe Spatial Object Type operation, the response time for sending the initial response shall be maximum 10 seconds in normal situation then, and still in normal situation, the download service shall maintain a sustained response greater than 0,5 Megabytes per second or greater than 500 descriptions of Spatial Objects per second.

...

The normal situation represents periods out of peak load. It is set at 90 % of the time."[29]

The performance requirements are too low to ensure normal operation of a service. The requirements of a service by the provider to allow traffic on the same level as non–INSPIRE services provided by Czech Office for Surveying, Mapping and Cadastre are much higher and the infrastructure on the server side is able to provide such requirements. Therefore, requirements must be exceeded multiple times if the service is expected to be used by the local users.

5.2 View Services

View services allows user to get data as a raster image. Technical Guidance on View Service[32] concedes only two ways of implementation – using ISO 19128 profile, describing Web Map Service (WMS) in version 1.3.0 or Web Map Tile Service (WMTS) in version 1.0.0. Web Map Tile Service is providing pre–defined tiles, thus it is not really suitable for data sets that are updated daily. Only WMS service is implemented for the Buildings and Cadastral Parcels themes publication. Moreover, Cadastral Parcels Extended was based on the national Cadastral Map provided only by WMS. Hence Cadastral Parcels Extended has no standalone view service.

5.2.1 Web Map Service in version 1.3.0

Web Map Service in version 1.3.0 is defined in the document OpenGIS Web Map Service (WMS) Implementation Specification[33]. The implementation of the service based on the Technical Guidance on View Services requires support of operations Get View Service Metadata and Get Map. Those operations are represented by operations GetCapabilites and GetMap in WMS based on ISO 19128 profile. Technical Guidance also requires Link View Service operation, which is not represented by any ISO 19128 profile operation. This operation shall "allow Public Authority or Third Party to declare a View Service for the viewing of its resources by Member State View Service"[32]. Making service metadata available in a national catalogue is recommended to be done with Discover Metadata operation of Discovery Service.

Operation Get View Service Metadata is represented by WMS GetCapabilities request. According to the document [33], GetCapabilites request shall return XML document response with structured metadata about the service itself, containing service name and abstract, information about contact person, fees and constraints, maximum allowed size of a map in pixels and capability metadata containing information about supported requests, layers and possible exceptions. Technical Guidance on View Services adds extended metadata with additional information. Additional information are mapped to the INSPIRE code lists.

Operation Get Map is represented as WMS GetMap request returning raster image. According to the document [33], GetMap request shall have parameters with bounding box, coordinate reference system, image format, layer and image resolution, portrayal style, language and dimension pair in case of more than two dimensional requests. Sample request rendering a map image with resolution 800×500 pixels of layer BU.Building in a given bounding box in a PNG format has its output in the Figure 5.1.

GetCapabilites response document contains allowed styles for every layer. The default style is defined in Data Specification documents in the chapter Portrayal. In the XML response it is called `inspire_common:DEFAULT`, but WMS allows users to define own styles and define them in a `user` key value pair in GetMap request.

5.2.2 Portrayal of data in View Services

Portrayal rules of Buildings data are described in the chapter 10 of the Data Specification on Buildings[1]. Data specification document defines default style for layers `BU.Building` and `BU.BuildingPart`. Buildings are portrayed as solid gray polygons with solid black outlines of given width (or solid dark grey circles in case of point geometry). Building parts are portrayed as transparent polygons with thinner solid black outline or as solid gray circles in case of point geometry.

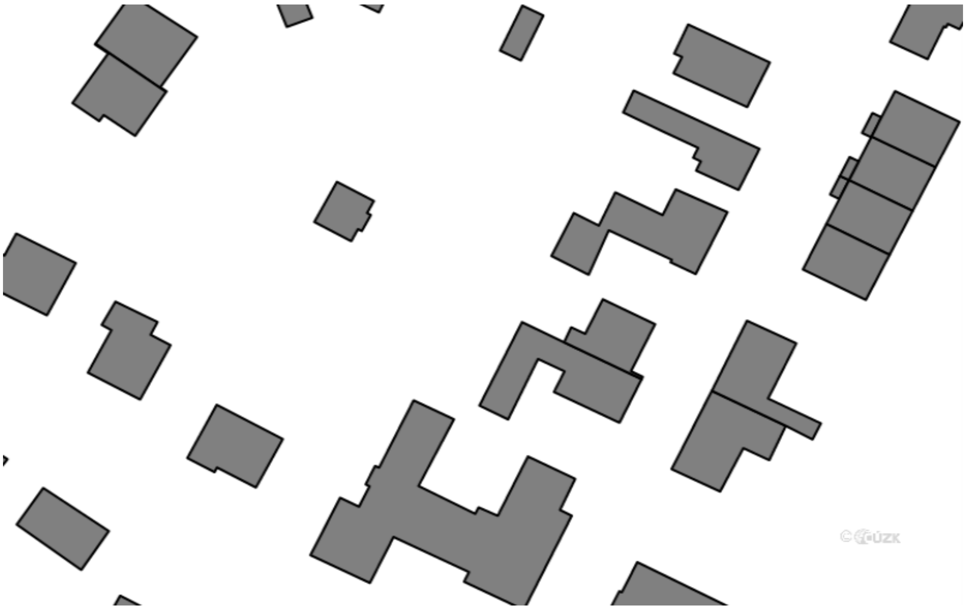


Figure 5.1: Output of WMS service requesting http://services.cuzk.cz/wms/inspire-bu-wms, rendering a map image with resolution 800 × 500 pixels of layer BU.Building in a given bounding box in a PNG format.

Data of Cadastral Parcels Extended does not have stand alone View Service, because the goal of application schema was to create vector representation for data used on the national level. Those data are already published by WMS as it is required by Cadastral Decree. View service for the theme Cadastral Parcels follow the portrayal rules described in the Data Specification on Cadastral Parcels[34].

5.2.3 Performance requirements of view services

The INSPIRE Implementation Rules set requirements on performance of view services as follows:

"For a 470 Kilobytes image (e.g. 800x600 pixels with a colour depth of 8 bits), the response time for sending the initial response to a Get Map Request to a view service shall be maximum 5 seconds in normal situation.

[...]

Normal situation represents periods out of peak load. It is set at 90 % of the time."[32]

During the testing occured some problems with view service performance. The times measured during testing were moving around 5 seconds. However it is quite difficult to measure, because it cannot be distinguished between the time spent on sending the image and creating it on the server side. This problem was solved by optimalization of data.

Requirement on the Service capacity is only 20 requests per second, which is much less than it is needed to succesfully run service for the needs of national users.

5.3 Metadata

According to the Implementation Rules shall be all datasets described by metadata according to the ISO 19115 and all services shall be described by metadata according to the ISO 19119.

Technical Guidelines on Metadata[28] defines which metadata elements from ISO 19115 and ISO 19119 are obligatory for INSPIRE data and services description.

According to the Implementation Rules, every data set shall have its own metadata and download service end–point. This problem is described in 5.1. Metadata are provided per one data set of the whole Czech Republic, same as service end–point. Metadata shall be generated automatically per real data sets.

Most of the information in metadata are stable – information about provider, area of data, INSPIRE theme, service end–points etc. The most variable part of metadata is Data or Service quality. Metadata describes quality based on the outputs of various tests, such as completeness of data or missing features.

Metadata are in a form of templates stored in the database and certain variables are replaced by the values from database for specific data by the PL/SQL scripts. Metadata are updated weekly.

Metadata are published via catalogue service (CSW) managed by the Land Survey Office. Contractor of the Land Survey Office was Intergraph, that recently became part of Hexagon. The metadata generated from the publication database for Cadastral Parcels Extended and Buildings are accessed by the Hexagon tool and published by the catalogue service from the service end–point `https://geoportal.cuzk.cz/getHTML.aspx`.

5.4 Technical realization

Data are transformed into GML in the software Marushka® which is also used for publication. Software supports implementation of View Services by WMS 1.3.0 and Download

Services by WFS 2.0.0. Support of ATOM is currently in progress. In themeantime is ATOM provided as designed and developed by Jaromír Rokusek (described in his diploma thesis [31]).

Software Marushka® is connected to the database and/or generated WKB files. Service requests are transformed into the SQL queries, which are then transformed into GML in the requested CRS. Query requesting pre–defined files return data files directly from the server.

In the case of queries limited by bounding box, WKB files are used instead of direct access to the database for both WMS and WFS.

Chapter 6

Conclusions

The dissertation thesis consists of four functional chapters describing the task of functional implementation of INSPIRE themes Buildings and Cadastral Parcels in the Czech Republic in a way that is not only fully compliant to the Implementing Rules of the INSPIRE Directive, but also provides features and attributes relevant to the national users.

6.1 Summary

The whole dissertation thesis consists of Chapters Introduction (1), Background (2), Analysis (3), Modeling, mapping and transformation (4), Publication (5) and Conclusions (6).

Chapter Introduction introduces the problem and sets the goals of the dissertation thesis. The most important part of the Introduction lies in the brief description of the problem and suggested solution.

The second Chapter – Background – focuses on the INSPIRE Directive. Reader is first acquainted with the legal status of INSPIRE and brief description of what INSPIRE is and why, how and when shall it be implemented. Summary of the implementation status in Europe and in the Czech Republic follows. The status of implementation in Europe is described in the obligatory Monitoring and Reporting. Monitoring takes place every year and in this dissertation thesis are compared data from 2017, 2018 a 2019. It confirms that the amount of data in the last three years is growing slowly and providers are now more focused on the quality. Reporting is done every three years. The last one published is from 2016. By the time of finishing this dissertation thesis was Reporting 2019 not yet published. The rest of the Chapter contains more detailed description of what exactly is needed for a data to be INSPIRE compliant, the role of metadata and services and brief description of technical specifications for INSPIRE themes.

The main goal of the Chapter Analysis is to analyze INSPIRE models required in the Data Specification documents, the status of technical implementation of those models in the form of XML Schemas and content of national data sets with the same or similar data as required by INSPIRE themes Buildings and Cadastral Parcels. The most important outputs of the analysis are:

- needs of national users on Cadastral Parcels are more complex than requirements and possibilities of the Data Specification on Cadastral Parcels,
- application schema Buildings Extended 2D, which is most suitable for use on the Czech data about Buildings, does not have proper technical implementation in XSD.

Therefore it is necessary to create application schema Cadastral Parcels Extended as an extension of INSPIRE theme Cadastral Parcels and its technical realization as XML Schema and also XML Schema for already existing application schema Buildings Extended 2D.

The key Chapter of the dissertation thesis is Modeling, mapping and transformation. This Chapter describes the process done in order to achieve the main goal of the dissertation thesis. The most important and innovative tasks of the dissertation thesis are:

- design of the new application schema extending Cadastral Parcels by the new features and attributes used at the national level,
- creation of new XML Schemas representing models of Buildings Extended 2D and Cadastral Parcels Extended application schemas.

Once the models and XML Schemas are ready, the implementation continues the same way as for any other already implemented schema (e.g. Addresses and Administrative Units, described in the master thesis[5]).

In order to make the implementation complete, data has to be published and described by metadata. The process was already described in other works and the Chapter Publication sums it up for temes Buildings and Cadastral Parcels Extended.

6.2 Contributions of the Dissertation Thesis

On the INSPIRE Conference 2017 in Strasbourg and 2018 in Anwerp was presented the interest of European Commission on extending the idea of interoperable data and services into the practical usage on the national level. Actually, thanks to the outputs of this dissertation thesis were those ideas already presented at those conferences – creation of XML Schemas for Buildings Extended 2D was presented on INSPIRE conference 2016[35] and national extension of Cadastral Parcels was presented in 2017[36].

The main practical contribution of the dissertation thesis is publication of data that are INSPIRE compliant, including standardized format and services, unified metadata, and at the same time contains all the information needed by the national users. Data sets bring additional value for national users and are fully compliant with all other INSPIRE data sets across Europe.

In the case of Buildings, newly created XML Schemas are as close to the representation of the application schemas Buildings Extended Base and Buildings Extended 2D as it gets without multiple inheritance and so they may be used across other European countries to publish Buildings according to the Buildings Extended 2D application schema.

Cadastral Parcels Extended were created exactly as a model of features present in the Czech Cadastre of the Real Estates. It brings value to the Czech users, European providers may use the application schema, XML Schemas and methods described in this dissertation thesis as an inspiration and guidance on how to extend INSPIRE models accoring to the national needs.

6.3 Future Work

Buildings were published in 2015 according to the Buildings Extended 2D application schema model. Cadastral Parcels Extended have the very first version of XML Schema published in 2017 and now are in the test regime. All the documentation needed for publication is now in the hands of Czech Office for Surveying, Mapping and Cadastre.

New Reporting shall come out in 2020, but data for it were already gathered in November 2019. Data sets and services and their metadata for the theme Cadastral Parcels Extended are not part of that reporting. It would be appropriate to gather statistics about the quality of the data.

Another statistic that shall be done is number of user accesses to the data of Cadastral Parcels Extended compared to the user access to the INSPIRE theme Cadastral Parcels (without extension) and national distribution of data of the Cadastre of Real Estates. For some relevant outcomes is needed aditional time for users to get used to the product and process data.

For the Buildings it would be interesting to compare existing and newly coming implementations in Europe. By exploration of the national needs and existing solutions shall be designed official INSPIRE XML Schema for Buidlings Extended Base and two subsequent Schemas BuildingsExtended 2D and Buildings Extended 3D. This shall be done by the European Commission. It may end up with non–confomrance of Czech data to INSPIRE and a new modeling and mapping process.

Last but not least recommendation on future work is regular revision of the models and schemas. As needs of the users may change, the technical representation of that needs shall change as well. It is not a purpose of data models to stay static and avoid changes – it must change in order to enhance the quality of services it provides.

This work is one of the steps to the Open Government Data [37][1] or open data infrustructure in general[39]. Future step may be moving to linked spatial data by the creation of links between data[40][41] with high quality[42].

[1]In the Czech Republic was a platform trying to achieve a goal of Geospatial Infrastructure, althought not really open[38].

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