

## **THE USE OF ONTOLOGIES IN THE SPATIAL PLANNING DOMAIN**

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### **INTRODUCTION**

The spatial planning system in many countries includes three levels: national, regional and local. Planning documents at each level have various degree of detail and scope of content. Spatial planning and cadastral data are the most important information provided by public administrations. The most essential document of all planning studies is the local spatial development plan – prepared at the local level – setting out the detailed rules for building and zoning conditions in an area. Its main purpose is to determine the designation of the area, which is the future land use. It is a legislative act, therefore, all findings contained in this plan are binding. Local plans consist of drawings which are integrally linked to the text. There is no uniform standard for either writing or publishing the plans. In accordance to the results of the Plan4all project [7,8,9,10], whose aim it was to harmonize planning data across Europe, access to these data and their distribution are different, depending on the existence of a clearinghouse, the state administration and the duties imposed on them, and, certainly, the law. In the field of spatial planning, a standardization of plans has been attempted for many years. Only some European countries have such standards, mainly for the publication the spatial planning data, e.g. Netherlands [1]. Also, steps have been taken toward an effective publication of plans over the internet and other possibilities for their further reuse. Over the past ten years many research institutions have intensified research into the use of ontologies and semantic networks. In the field of spatial planning work has been done to augment planning processes with ontologies and semantic networks. For example, the use of such solutions was noted by the authors of the LegalAtlas application, developed by the Leibnitz Center of Law [2]. The solution aims to improve access to the regulations written in the spatial planning documents. Another example is the application of ontologies to the management of planning documents [3], as well as to describe the methodology for planning decision support [4].

### **THE DOMAIN OF SPATIAL PLANING**

The natural environment is a valuable common property, with such assets as landscape and natural resources, and as such has to be protected. Necessary compromises result from trying to bring together this need for protection with property rights, personal freedoms, and commercial activities. As usual, when conflicts are possible between citizens, or between a citizen and various social groups, or the society as a whole, the state must obviously step in as a regulator. The legal system is the mechanism for these regulations. These are the origins and the basis for creating the spatial planning system. Its goal is to reconcile the individual rights, the economical effectiveness of managing the space, protection of the environment and the resources which could be irreversibly lost. The spatial planning system is thus based on the state established laws, which enable the government to create spatial policies and give it the necessary instruments. That is, the system obligates the state authorities on the one hand to create the documents governing the spatial policy, and on the other hand and to make laws to enact this policy.

### **SPATIAL PLANS - ELEMENT OF THE INFORMATION SOCIETY**

A planning document takes into account both the land conditions, and all the constraints resulting from the requirements of:

- environmental protection, natural resources, and landscape;
- cultural heritage protection;
- rational use of existing technical infrastructure, including the provisions for the economical effectiveness for the development of these systems; and
- the various elements of land transport systems, including an efficient use of the existing infrastructure.

Clearly, the source data, largely spatially referenced data, makes up a rich database of information about the environment. Likewise, the body of the planning documents describe many aspects of the society, and in turn has an impact on its social, cultural, and economic development. From the point of view of the administration the spatial planning system appears mainly as a regulatory instrument, with the purpose of

making a rational use of space and protecting the environment. On the other hand, from the social point of view it is a rich source of information, influencing economic, cultural and educational development, as well as the health care system and general quality of life. Access to such information also enhances active participation of the society in the spatial management processes, and generally in the social and political life of the community and the country.

There are several ways to disseminate planning information to stakeholders:

1. As static images (e.g. JPG), which present the planning information in a fixed manner (hopefully, with a legend!), but which cannot be integrated with other data or edited.
2. As basic vector (CAD) data (e.g. DXF), which allow the planning information to be edited and the display of the information to be modified, but which does not allow the data to be integrated with other data sets.
3. As geographical data (e.g. SHP files), which allow the planning information to be integrated with other geographical data sets and allow models to be run on the data, etc. However, the planning information often cannot be integrated with planning information in neighbouring areas, because of the different taxonomies and coding schemes used by the different planning authorities for their planning information.
4. As ontological data (e.g. OWL) in combination with the geographical data, which then allows the integration of planning information from multiple planning authorities, because the ontology provides a common context for translating the different taxonomies into one's preferred taxonomy. Further, the ontology allows one to perform inference on the planning information.

When data is expressed with the use of ontology modeling language, semantics are automatically embedded in the model, facilitating understanding and allowing reuse of the data in different scenarios, which is the purpose of an SDI. In geographical data the identifiers are local to a specific database, therefore integration of data from different sources could result in duplicated identifiers. In contrast, in ontological data (e.g. OWL or RDF) a global identifier in the form of a Uniform Resource Identifier (URI) can be assigned to each object, predicate and subject, so that when data is integrated from different sources, each identifier remains unique. In geographical data the data structure is fixed according to the application schema in the database (i.e. number of attributes and their types), whereas in ontological data represented by graphs there is more flexibility. Additional relationships can be added to the graph at any time. In RDFS and OWL additional information can be inferred based on existing relationships, which is especially important in the process of building a spatial information and knowledge infrastructure. Whenever OWL and RDFS are published on the Web they have the possibility of becoming a de facto standard.

### **THE PRACTICE OF CREATING SPATIAL PLANNING DOCUMENTS**

Currently, each district creates its own local model and information recording standard. Moreover, even in one district many different models are introduced by different plan creators, different purposes of the plans, and different scales of the project. These differences concern the following aspects:

1. Splitting the spatial plan resolution into smaller editing units.
2. The land reference system, as the basic plan area division unit, has the following variants:
  - a. The division of the text of the plan enacting resolution reflects the sequence of the items of the act and for each item a further indication is given with the list of sites to which this decision relates.
  - b. The findings for each site is a self-contained editorial unit (paragraph, section, area card, which might take the form of a table), which completely and exhaustively specifies all the findings for the area, with the following possible options:
    - each area card refers strictly to one area; or
    - the cards contain the findings for groups of areas with identical management rules – the areas may be differentiated by numbers or not.
  - c. The findings can be broken down into:
    - general, relating to the whole plan area;
    - specific, concerning specific subareas, grouped in paragraphs, sections, or area cards; or
    - other variants as combinations of the above.
3. The method of splitting the area of the spatial plan:
  - a. flat division: the plan area is divided with lines into atomic subareas;
  - b. multilevel division:

- the plan area is divided into subareas (termed: functional zones, functional areas, and others) containing further planning areas of different purposes subdivided by lines (development areas, road areas, technical infrastructure, etc.);
- the plan area is divided by lines directly into planning subareas, but within those subareas are internal subdivisions which have different purposes (sometimes further specified by additional constraints, and sometimes augmenting the main purpose or other solutions); or
- a multilevel variant as a combination of the above.

Aside from the local variants, there are variants related to different purposes of plans. For example, if a spatial plan was created solely for the purpose of prohibiting development, or for enforcing conversion to forests, some findings, which are not mandatory, may be omitted.

### **STANDARDS IN THE PLANNING DOMAIN**

Spatial planning is hard to formulate in data modeling specifications, application schemas and metadata profiles that have been developed for spatial data infrastructures. The documents covering spatial policies are descriptive, without a clearly defined structure – the law and the regulations determine only the issue without specifying the data model.

An additional factor hampering the standardization is the multitude of purposes for which the plans are created. For an example, a local plan can be made to prohibit development in some area, to designate it for conversion to forests, or to open up the area to development: dwelling, services, industrial, or other, including mixed. Such purposes may also be more specialized, pursuing advanced tasks of spatial policy. For example, the local plan could give rise to legal actions relating to the rehabilitation of degraded areas, revitalization and regeneration of downtown areas, location of important and complex public structures: roads, technical infrastructure (energy, waste disposal, etc.). In order to create documents for such diverse purposes, they have to take on different forms, use different recording means, different systems for designating sites for various purposes and principles of management.

Under the current legal conditions in Poland, a potential standard for recording a local spatial plan must satisfy the following:

1. Enable unambiguous recording of all the planning contents specified in the current planning and spatial management law and related legal acts.
2. In order to provide the historical continuity for previous documents, the standard would have to also incorporate the earlier legal regulations (pre-2003) and main “styles” of the currently used recording means that are in use in many districts and counties. A lack in this respect may prove to be decisive in assessing the value of such a standard format.
3. It should be usable as an interchange standard for planning data between different systems capable of data export and import.

Particularly the second item above seems practically impossible to satisfy; indeed, it is hard to imagine to just be able to collect all the recording systems in use in Poland, including the most exotic ones. But even the first requirement may turn out to be demanding too much. So considering the complex spatial plan structure and their specifics, creating a standard for their recording is a difficult project. It demands determination and cooperation among the spatial planning community, as well as an unambiguous formulation of the law.

Spatial plans serve double roles. The first is official (they form a basis for administrative decisions), and the second is informative for the society. For the first role the standardization established by the binding acts of law seems to be crucial. The publication standard for plans is more important for the second, informative role. The way a plan is published affects its informative scope, the information potential, and the ability of its further reuse. A plan could be published in different ways – in raster or vector formats, in GIS, including the publication of the associated metadata.

The authors undertook the task to record plans in the OWL data model, as one giving more possibilities for further use of these data. The added value here is that knowledge can be derived.

### **INTRODUCTION TO ONTOLOGIES**

Ontologies are considered to be a core element of the Semantic Web, which is defined as “the extension of the World Wide Web that enables people to share content beyond the boundaries of applications and websites”. It has been described in rather different ways: as a utopic vision, as a web of data, or merely as a natural paradigm shift in our daily use of the Web.”[5]. One of the first definitions of ontology was Gruber’s definition of an ontology as an „explicit specification of a conceptualization”[6]. Another definition states an ontology as a „formal specification of a shared conceptualization”. Also, such a conceptualization should be expressed in a formal way. In 1998, Studer et al.[11] merged these two

definitions stating that „An ontology is a formal, explicit specification of a shared conceptualization”. Generally ontologies describe some part of reality, trying to answer the questions: What kinds of things exist or can exist in the world, How can these be classified?, What manner of relations can those things have to each other? Ontology elements are classes, instances and their relationships. The number of formal ontology languages is not too large: Ontobroker, SHOE (Simple HTML Ontology Extensions), OIL (Ontology Inference Layer or Ontology Interface Layer), DAML (DARPA Agent Markup Language)+ OIL (Ontology Inference Layer), OWL (Ontology Web Language). Most of the newer languages are based on RDF (Resource Description Framework) and RDFS (Resource Description Framework Schema) model.

### A CLOSER LOOK

The description of datasets and the objects contained therein using ontologies is a way of representing knowledge about space. Having an ontological representation of an object or a system enables one to construct an automated and rigorous procedure to acquire and complete the knowledge of such object or instances of a system. This is how languages like RDF, RDFS, OWL, and SWRL are used. Following here are some examples of ontologies, describing the spatial planning domain:

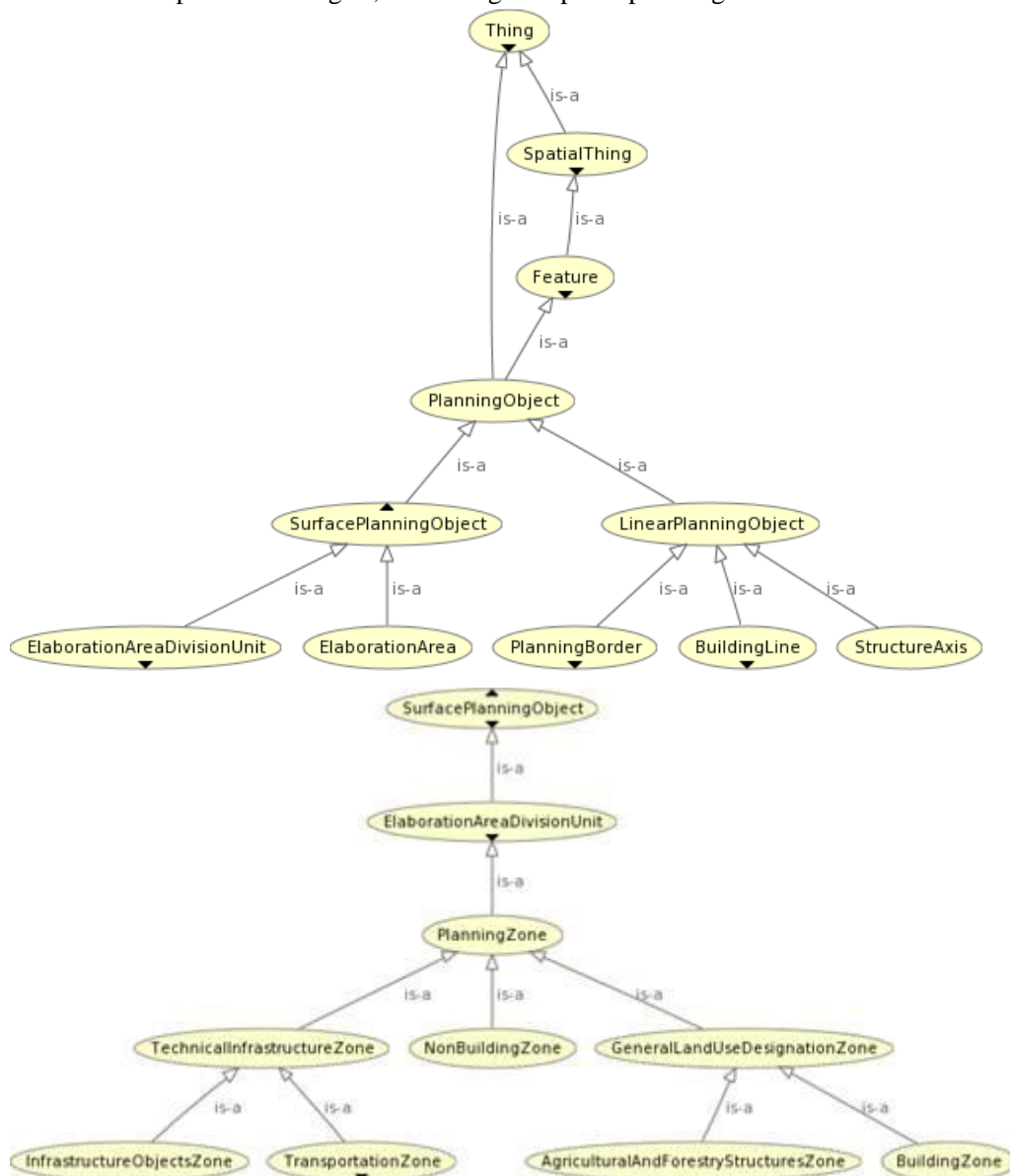


Figure1. Fragments of a graph representing an ontology in the spatial planning domain

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<spatplan_plan_structure:PlanningZone rdf:ID="02_P0">
  <rdf:type rdf:resource="http://www.seegis.st7.eu/owl/spatplan_plan_structure.owl#GeneralLandUseDesignationZone"/>
  <spatplan_zone_schema:planningZoneSymbol rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">02_P0</spatplan_zone_schema:planningZoneSymbol>
  <spatplan_zone_schema:landUseDesignationFunctionalPriorityRef rdf:resource="http://www.seegis.st7.eu/owl/egp2_top_funkcyjnalny_pozostawieniu.owl#M1"/>
  <wgs84_pos:lat rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">53.567253001973</wgs84_pos:lat>
  <wgs84_pos:long rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">14.5110557604306</wgs84_pos:long>
  <wgs84_pos:lat_long rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">53.567253001973;14.5110557604306</wgs84_pos:lat_long>
  <rdf:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">
    </rdf:comment>
  <rdf:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">02_P0</rdf:label>
  <gn:parentFeature rdf:resource="http://sws.geonames.org/7533330/">
  <gn:parentCountry rdf:resource="http://sws.geonames.org/798544/">
  <gn:parentADM1 rdf:resource="http://sws.geonames.org/3337499/">
  <gn:parentADM2 rdf:resource="http://sws.geonames.org/7530844/">
  <gn:parentADM3 rdf:resource="http://sws.geonames.org/7533330/">
  <spatplan_omnastic:placeName rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">Tatynia</spatplan_omnastic:placeName>
  <spatplan_omnastic:parentPlaceName rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">Gmina Police</spatplan_omnastic:parentPlaceName>
  <spatplan_omnastic:parentPlaceName rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">4326611045</spatplan_omnastic:parentPlaceName>
  <spatplan_omnastic:geodeticTeryCode rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">321104_5</spatplan_omnastic:geodeticTeryCode>
  <spatplan_omnastic:numberOfGeodesicSubdivision rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">0010</spatplan_omnastic:numberOfGeodesicSubdivision>
  <rdf:isIdentifiedBy rdf:resource="http://www.seegis.st7.eu/xml/egp2_resources/egp2_tatynia_police.xml#GAL037EE-8F05-4D49-AAF3-98A05013CF8D"/>
  <spatplan_zone_schema:descriptionDocumentEditorialUnitReference rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xml:lang="pl">apar.
37</spatplan_zone_schema:descriptionDocumentEditorialUnitReference>
  <spatplan_zone_schema:planningZoneNumber rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">02</spatplan_zone_schema:planningZoneNumber>
  <spatplan_zone_schema:planningZoneLandUseDesignCompletionFunction
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">M1</spatplan_zone_schema:planningZoneLandUseDesignCompletionFunction>
  <spatplan_zone_schema:planningZoneLandUseDesignFirstFunction
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">M1</spatplan_zone_schema:planningZoneLandUseDesignFirstFunction>
  <spatplan_zone_schema:planningZoneLandUseDesignSecondFunction rdf:datatype="http://www.w3.org/2001/XMLSchema#string"/>
  <spatplan_zone_schema:areaSquareMeters rdf:datatype="http://www.w3.org/2001/XMLSchema#double">9050.0294375</spatplan_zone_schema:areaSquareMeters>
  <spatplan_zone_schema:areaRectars rdf:datatype="http://www.w3.org/2001/XMLSchema#double">0.90500294375</spatplan_zone_schema:areaRectars>
  <spatplan_zone_schema:adjacentPlanningZone rdf:resource="http://www.seegis.st7.eu/owl/egp2_resources/plan_zones_spatrelations.owl#03_P0"/>
  <spatplan_zone_schema:adjacentRoad rdf:resource="http://www.seegis.st7.eu/owl/egp2_resources/plan_zones_spatrelations.owl#22_KD0"/>
  <spatplan_zone_schema:existingLandUseConditions rdf:resource="http://www.seegis.st7.eu/owl/egp2_resources/plan_zones_spatrelations.owl#0010-540_R1"/>
  <spatplan_zone_schema:existingLandUseUnitRef rdf:resource="http://www.seegis.st7.eu/owl/egp2_resources/plan_zones_spatrelations.owl#0010-540_R1"/>
  <spatplan_zone_schema:planningZoneExistingLandUseCond rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xml:lang="pl">02</spatplan_zone_schema:planningZoneExistingLandUseCond>
</spatplan_plan_structure:PlanningZone>

```

Figure 2. Fragment of a local plan defining an area, recorded in a graph based on a spatial planning ontology

In the passage in Figure 2 one can find a wealth of information showing the context of the analyzed area:

- location: the properties in the elements wgs84\_pos:lat\_long, wgs84\_pos:lat, wgs84\_pos:long – which give geographic coordinates, the properties gn:parentCountry, gn:parentFeature, gn:parentCountry, gn:parentADM1, gn:parentADM2, gn:parentADM3 showing the membership to administrative units of levels 1, 2, 3 – the reference rdf:resource="http://sws.geonames.org/7533330/" indicates a resource providing much interesting information about the locality containing the object under examination, including a Wikipedia page address,
- the property spatplan\_zone\_schema:planningZoneLandUseDesignFirstFunction is defined in the planning ontology discussed here, and refers to the resource containing the functional dictionary of terrain designation,
- the property spatplan\_zone\_schema:adjacentPlanningZone shows the neighborhood of other planning areas, and also contain a rich description of their conditions; this permits an easy analysis of their planning context,
- the properties spatplan\_zone\_schema:existingLandUseUnitRef and spatplan\_zone\_schema:planningZoneExistingLandUseCond refer a planning area to geodesic resources, here describing the conditions of the current land use legal status.

**CONCLUSIONS**

At this stage of the development of information zone technology, it is questionable whether any further functionality improvements for SDIs and the World Wide Web can be achieved without metadata. The development of metadata for SDIs is compatible with OGC specifications and ISO standards, while metadata for the Web are developed as World Wide Web Consortium (W3C) standards – including RDF and OWL. According to INSPIRE and OGC metadata are made available through catalog services. Preparing a metadata profile at the dataset level was a difficult task, but has been done for all INSPIRE themes. Also, a draft metadata profile for spatial planning was proposed under the Plan4all project. Preparing metadata for the features of spatial plans will be much more difficult and expensive. For this reason, the use of ontologies to describe the spatial planning domain is an interesting alternative because it allows the possibility of global identifiers in ontological data, the flexibility in the graph representation, semantics embedded in the ontology and the fact that additional information can be inferred based on existing relationships. These are essential for establishing a spatial information and knowledge infrastructure.

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