Interoperability Solutions for European Public Administrations

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Core Location Pilot

CORE LOCATION VOCABULARY

Interconnecting Belgian National and Regional Address Data

Deliverable

JOINING UP GOVERNMENTS

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Disclaimer:

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1 Introduction

This document describes the outcome of the Core Location Pilot 'Interconnecting Belgian National and Regional Address Data', which was carried out in the context of Action 1.1 of the Interoperability Solutions for European Public Administrations (ISA) Programme of the European Commission in the period November 2012 – February 2013.

The pilot demonstrates that:

- The **Core Location RDF Vocabulary** can be used as a foundational RDF Vocabulary to *homogenise address data* that originate from disparate organisations and systems;
- The Core Location RDF vocabulary can be **extended *flexibly*** with experimental INSPIRE RDF vocabularies[1] (i.e. transport networks and administrative units);
- **HTTP URI sets** can be derived from INSPIRE Unique Object Identifiers for address data, allowing the creation of harmonised Web identifiers for spatial things and spatial objects such as addresses ;
- A **linked data infrastructure** can provide access to *homogenised, linked*, and *enriched* location data using standard Web-based interfaces (such as HTTP and SPARQL) and Web-based languages (such as XHTML, RDF+XML), on top of either:
    - existing **relational/spatial database systems**, by applying database-to-RDF conversions, or**;**
    - existing **INSPIRE XML data**, by applying XSLTs to automatically generate RDF, starting from XML-encoded INSPIRE-compliant meta/data;
- The use of standard Web interfaces (such as HTTP(S) and SPARQL) can **simplify the use of location data** for both humans and machines.

[1] Please note that the INSPIRE RDF vocabularies and concept schemes implicitly mentioned is this document are not and should not be referred to as the "official" or "recommended" INSPIRE RDF vocabularies and SKOS concept schemes. They are just experimental, and whether they can be re-used also outside the scope of the pilot is yet to be decided.

1.1 Glossary

The table below contains an overview of terms and acronyms used throughout this document.

Table 1 – Glossary

Term / Acronym	Description
Brussels UrbIS	Brussels Urban Information System
CRAB	Authentic source of address data in the Flemish region. (CRAB - Centraal Referentie Adressen Bestand)
GRB	Large-scale spatial reference data of the Flemish Region. (GRB - Grootschalig Referentie Bestand)
HTML	Hypertext Markup Language
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
ISA Programme	The Interoperability Solutions for European Public Administrations Programme of the European Union
ITGI	Topogeographic Inventory maintained by the NGI / IGN.
PICC	Projet Informatique de Cartographie Continue
QoS	Quality of Service
RDF	Resource Description Framework
SDI	Spatial Data Infrastructure
SKOS	Simple Knowledge Organization System – RDF Vocabulary for the representation of key reference data such as code lists, and taxonomies.
SPARQL	SPARQL Query Language for RDF
SPW	Service Public de Wallonie
URI	Uniform Resource Identifier
URI set	A collection of reference data published using URIs, about a single concept, governed from a single source.
URL	Uniform Resource Locator

1.2 Addressing vocabularies

Two vocabularies have been used in the context of this pilot:

1. The **Core Location Vocabulary** is a simplified, reusable and extensible data model that captures the fundamental characteristics of a location, represented as an address, a geographic name, or a geometry [Location]. It is specified as a UML Static Model, an RDF Schema, and an XML Schema.

   The vocabulary was developed in the period December 2011 – May 2012 by a multi disciplinary Working Group, with a total of 69 people from 22 countries, 18 EU and 4 non-EU countries (USA, South-Africa, Norway and Croatia), and several EU Institutions. The Working Group was co-chaired by Paul Smits, Adrea Perego, and Michael Lutz of the European Commission INSPIRE team. On 23 May 2012, the Coordination Group of the ISA Programme endorsed[2] version 1.00 of the combined specification of the Core Business, Core Location and Core Person Vocabulary [Business, Location, Person]. Although endorsement does not make the specifications legally binding, it is an important milestone as the EU Member States acknowledge the work and commit to further exploit and disseminate it at national level. The W3C Location and Addresses Community Group [locadd] is to review the existing efforts such as the Core Location Vocabulary and assess whether any use cases would be served by harmonization and/or new standardization work. It may produce specifications or use cases and requirements documents, which may be proposed for adoption by the W3C Government Linked Data (GLD) Working Group.

2. The **INSPIRE Data Specification on Addresses** [INSPIRE] highlights the mandatory and the recommended address elements related to the implementation of INSPIRE. The overall concept of this data specification is that an address has a "**locator**", e.g. an address number that enables a user to distinguish it from the neighbouring addresses; and a geographic position, which enables an application to locate the address spatially. To identify the address unambiguously in a wider context an address must be associated with a number of "**address components**" that define its location within a certain geographic area. Each of the address components represents a spatial identifier, for example the name of a road, district, postcode, municipality, region or country. Four subclasses of address components are defined: administrative unit name, address area name, thoroughfare name and postal descriptor.

   The INSPIRE data specification for Addresses is expected to be become an application profile of the forthcoming **ISO Addressing standard** [ISO-19160].

[2] 2012-05-30, ISA Member State representatives endorse key specifications for e-Government interoperability
http://joinup.ec.europa.eu/news/isa-member-state-representatives-endorse-key-specifications-e-government-interoperability

How does the Core Location Vocabulary relate to the INSPIRE data specifications [INSPIRE]? The INSPIRE data specifications are legally binding. For addresses, Core Location can be seen as a subset of the INSPIRE address specification, as it based on the INSPIRE AddressRepresentation class. The Core Location Vocabulary has an RDF Schema representation, whereas the INSPIRE data specifications are presented as W3C XML Schemas. Despite these differences, it is important to highlight that the Location CV and INSPIRE are ***complementary***, and not two different approaches for doing the same job and requiring two separate implementations. This pilot also demonstrates that a Linked Data service can be implemented on top of an INSPIRE implementation.

Table 2 – Namespace prefixes used in this document

prefix	namespace
ad	http://inspire.ec.europa.eu/def/ad/
au	http://inspire.ec.europa.eu/def/au/
net	http://inspire.ec.europa.eu/def/net/
ic	http://inspire.ec.europa.eu/def/ic/
tn	http://inspire.ec.europa.eu/def/tn/
tnro	http://inspire.ec.europa.eu/def/tnro/
EPSG	http://www.opengis.net/def/crs/EPSG/0/
ex	http://example.com/
geo	http://www.w3.org/2003/01/geo/wgs84_pos#
locn	http://www.w3.org/ns/locn#
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#

1.3 Stakeholders

The table below lists the stakeholders involved in this pilot and their role. Further information about the spatial data landscape in the Belgian public sector can be obtained from the report 'Spatial Data Infrastructures in Belgium: State of play 2011' [SDI-EU].

Table 3 – Stakeholders and Roles [SDI-EU]

Stakeholder	Description
AGIV	The Flemish Agency for Geographic Information (AGIV - Agentschap voor Geografische Informatie Vlaanderen) is an external autonomous agency created in the context of the "GDI Vlaanderen" decree, responsible for the development of the SDI of the Flemish Region. It mainly supports the development and functioning of the SDI but also plays a role in data production, e.g. through the production of large scale reference data (GRB). **Role in the pilot**: AGIV provided a sample dataset from its CRAB address register [CRAB], participated in coordination meetings, and reviewed the work carried out.
CIRB	The IT center for the Brussels Region (CIRB – Le Centre d'Informatique pour la Région Bruxelloise) provides IT services and support to more than 250 regional and local public administrations in the Brussels Capital Region. CIRB is the main actor involved in the regional SDI Brussels UrbIS, containing among others more than 218.000 address points. **Role in the pilot**: CIRB provided a sample dataset from its UrbIS spatial database, participated in coordination meetings, and reviewed the work carried out.
bpost	bpost is a public limited liability company that provisions postal services in the Belgian market. Bpost has considerable expertise in address recognition. **Role in the pilot**: bpost reviewed the pilot and is a partner in the BeSt Add project.
Civil Register	The Belgian Civil Register contains the official addresses of natural persons, as they are entered when registering their place of residence.
DGSEI	The Directorate General Statistics and Economic Information (DGSEI) is in charge of the national (official) statistics in Belgium. **Role in the pilot**: DGSEI maintains the codelist for Belgian administrative units [Admin-Geo]. DGSEI has been informed of this pilot.
FEDICT	As a federal public service, FEDICT defines and implements the federal e-government strategy. The Belgian regional address registers are involved in a long-running project (the BeST project) to set up a federal infrastructure for interconnecting the Belgian national and regional address registers (the Brussels, Flemish, and Walloon regions). As FEDICT plays a coordinating role in the BeSt Add project. **Role in the pilot**: FEDICT supported the proposed pilot from the very

	beginning and set up an initial meeting with the BeSt Add partners.
SPW	The General Secretariat of the Wallonia Public Service (SPW - Service Public de Wallonie) coordinates a committee created in the context of the 2011 Decree on the Walloon SDI, the Strategic Committee for geomatics, which is composed of representatives of the Walloon public service; the public institutions; the local authorities; the crisis centres; and the utility companies. A main project in the Walloon SDI is the 'Projet Informatique de Cartographie Continue' (PICC) to produce a very large scale (1:1.000) reference database **Role in the pilot**: SPW provided a sample dataset from its PICC address register, participated in coordination meetings, and reviewed the work carried out.
NGI /IGN	Belgian national mapping agency (NGI/IGN - Nationaal Geografisch Instituut / Institut Géographique National) is a semi-public institution under the supervision of the Minister of Defence of the Federal Government. It is mandated to build the federal Spatial Data Infrastructure (SDI) as required by the INSPIRE Directive. NGI will set up a broker infrastructure providing access to spatial data and its descriptive metadata provided by various other public administrations in Belgium, including the three regional SDIs. The NGI develops and maintains the ITGI database, containing among other things information on roads and road segments. **Role in the pilot**: The NGI provided a sample dataset from its ITGI road segments database, participated in coordination meetings, and reviewed the work carried out.
European Commission INSPIRE team	The INSPIRE team consists of staff of the European Commission from the three DGs, DG Environment, Eurostat and JRC. Its role is to coordinate the development of the INSPIRE Implementing Rules as foreseen by the INSPIRE Directive. The INSPIRE team is also leading two related actions of the ISA Programme, namely Action 2.13 on the European Union Location Framework (EULF) and Action 1.17 on the re-usable INSPIRE reference platform. **Role in the pilot**: The Commission INSPIRE team co-chaired the Working Group responsible for the Core Location Vocabulary. It will review the work carried out.
ISA Programme	The Interoperability Solutions for European Public Administrations (ISA) Programme of the European Commission supports and facilitates efficient and effective cross-border electronic collaboration between European public administrations. The programme aims to enable the delivery of electronic public services through improving the availability, interoperability and re-use of data and by sharing common solutions. **Role in the pilot**: The ISA Programme has initiated the pilot, reviewed the work carried out, and financed it.

1.4 Business need

Currently the access to address data in Belgium is impeded by the following obstacles:

1. **Address data fragmentation**. The address data at federal level and for each of the three regions is housed in isolated registries, which hampers data integration as it is not possible to get an overview of all address data from a single point of access. In the public sector, there are among others the following providers of address data:
   - **Civil register** contains the official addresses of natural persons, as they are entered when registering their place of residence.
   - ***NGI /IGN*** maintains road segment data, including references to the identifiers and street names of the Civil Register – where available.
   - **AGIV** keeps address data for the Flemish region in its CRAB register the data is maintained in collaboration with the Flemish municipalities;
   - **CIRB** maintains address data for the Brussels Capital Region in its UrBIS; and
   - **SPW** maintains address data for the Walloon Region in PICC.
2. **Heterogeneous address data formats**. Address data is provided to different specifications and standards.
3. **Lack of common identifiers**. Entities like addresses, administrative units, roads, buildings, and cadastral parcels are not identified by well-formed identifiers so making it hard to reconcile data coming from different sources about the same entity.

Because of these obstacles 'consumers' of address data, such as national, regional, and local public administrations, businesses, and citizens, make limited use of the these registers. Address data remains unlinked, of low quality and non-interoperable. The current situation is depicted in Figure 1.

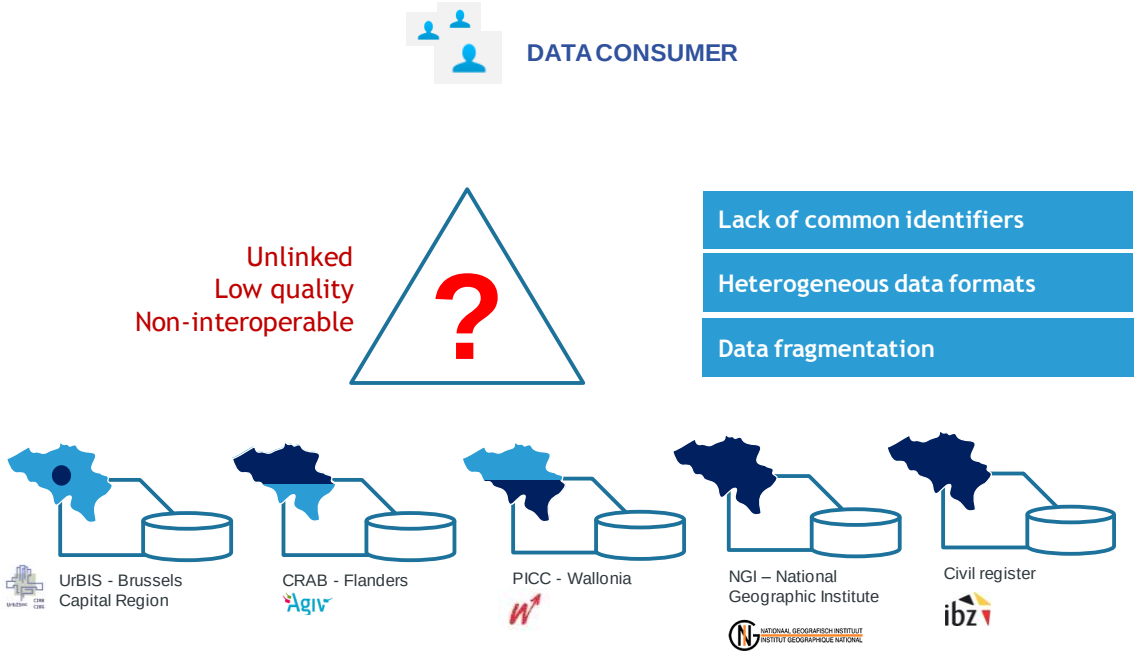


Figure 1 – Current situation: address data is fragmented across various registers

These challenges hamper the re-use of address data and so most organisations in the public and private sectors maintain their own and systems with address datasets that are of low quality, unlinked, and non-interoperable. Figure 2 depicts a situation where two different organisations maintain unlinked and non-interoperable address data. This pilot will demonstrate that the Core Location Vocabulary and experimental INSPIRE RDF vocabularies can help overcome the fragmentation, heterogeneity, and lack of common identifiers for address data in the Belgian context, and through this will point to a generalizable method for harmonising address data.

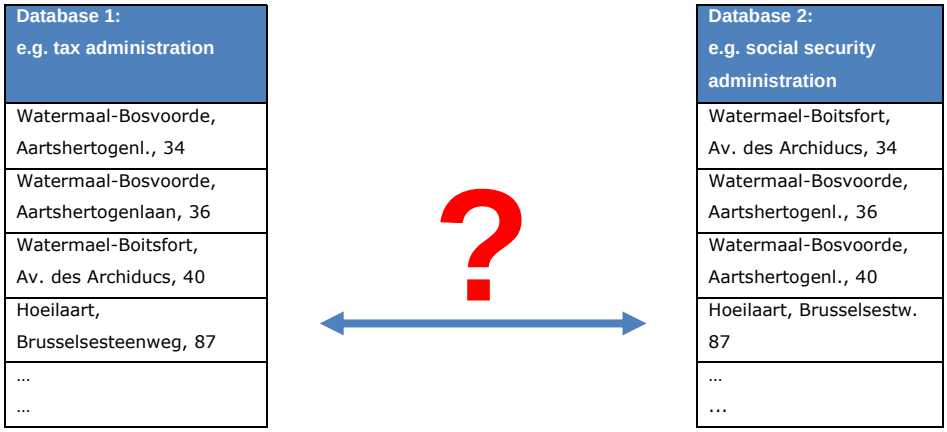


Figure 2 – The Core Location Vocabulary prevents address fragmentation

1.5 Proposed solution

This pilot investigates how the core location vocabulary and related INSPIRE data specifications on addresses can be applied to aggregate address data from various sources and contribute to overcoming the obstacles described above. In particular, the pilot demonstrates how to use the core location vocabulary – enriched with a number of experimental INSPIRE RDF vocabularies – to publish data from the Belgian federal level and the three Belgian regions as **linked data** [LinkedData]. It entails the following steps:

1. Develop (provisional) **URI sets** enabling Belgian addresses and/or streets to be uniquely identified and looked up on the Web by well-formed HTTP URIs;
2. Represent existing address data from the federal and regional road and address registers using the **core location RDF vocabulary** and experimental INSPIRE RDF vocabularies;
3. Put in place a **linked data infrastructure** that will allow querying homogenised Belgian address from a SPARQL endpoint.
4. Demonstrate the value of the linked data infrastructure to **disambiguate**, **lookup**, and **link** address data using simple Web-based standards such as HTTP, XML, and RDF.

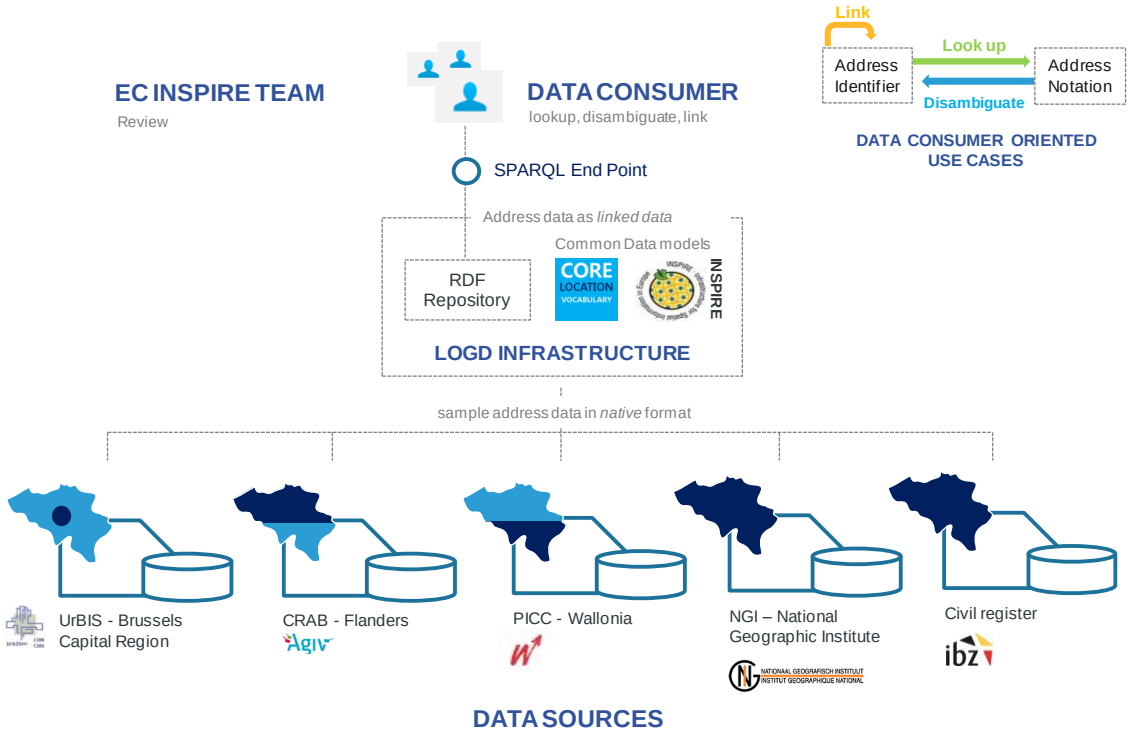


Figure 3 – The Core Location Vocabulary enables the benefits of *linked* address data

1.6 Complexities around address data not solved in this pilot

Addressing is a complex matter. It is therefore also important to acknowledge that a number of complexities around the use of address data are not solved in this pilot, as these problems relate to the existing systems in which address data are maintained and quality assured during the their **lifecycle**. In general, the following difficulties arise:

- **Different address types**: Addresses are used for different purposes; for example postal delivery versus emergency services. **Postal addresses** are used to locate a mailbox. **Physical addresses** are used to locate a building, cadastral parcel, or a person. In some situations postal and physical addresses might be significantly different.
- **Meaning of the geographic position**: even when geographic positions are linked to objects (cadastral parcels or buildings), there are no conventions to encode the precise meaning of these positions. The resulting lack of meaning may result in suboptimal data quality. In CRAB the meaning of an address position is known.
- **Heteronyms**: there exist roads with the same name within a single municipality;
- **Vernacular names and historic names**: Whereas governmental address registers have the mission to record the official street name (e.g. the CRAB address register in Flanders), many use cases require vernacular street names. Similarly, people keep using historic street names, they can remain in use for many years.;
- **Geodetic reference systems and projections**: datasets use different geodetic reference systems and projections. The NGI provides an online transformation module and software to convert between Lambert 72 and Lambert 2008 projections;
- **Complex numberings**: in Belgium municipalities maintain address data and use different conventions for address numbering. According to Bpost, the city of Ghent, for example, assigns “street numbers” (building identifiers) to individual apartments in a building. In some cases this means that mailboxes within apartments can be located by these numbers, as illustrated in Figure 5. It is challenging to encode such semantics in an adequate data model. In the case of the Core Location Vocabulary and INSPIRE data specifications on addresses this requires the use of different locator designator types. This is also illustrated in Figure 4 taken from the INSPIRE data specifications: different address notations can be used to locate the left apartment on the first floor of entrance 6 of building 360 on the Mainstreet.

To address these complexities, the CRAB address register was setup in the Flemish Region as an authentic source of address data and the Belgian Federal and regional governments are working together on the BeSt Add (Belgian Streets and Addresses) project to define an address standard and authentic source at the federal level.

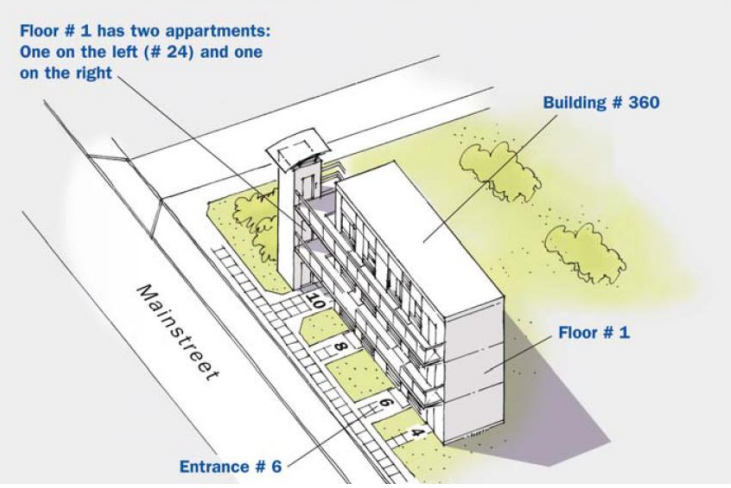


Figure 4 – Address locator designators [INSPIRE]

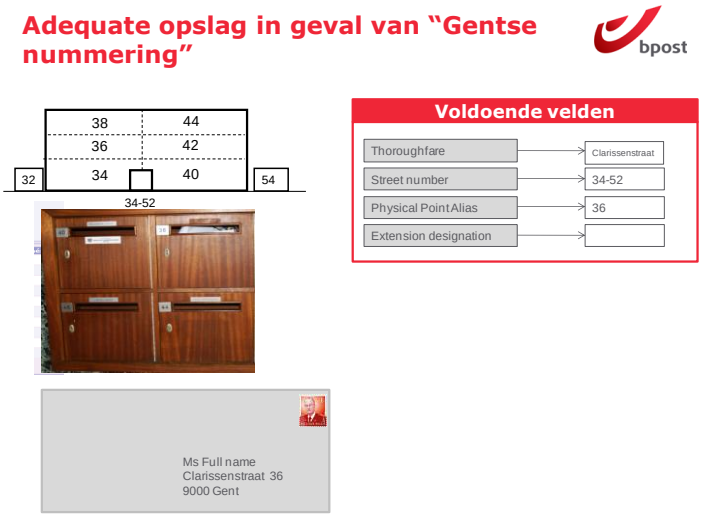


Figure 5 – Complex address numbering [Bpost]

1.7 Use cases

The pilot will demonstrate the generic use cases depicted in Figure 7. For each use case, we indicate how this use case may be relevant in practice.

- **Use Case 1: Disambiguate** an address notation by attributing an identifier (a URI) to it. The user sends a query to the combined linked data infrastructure to determine which address identifier corresponds to a particular address. The linked data infrastructure might return zero, one, or more possible results that match to a certain degree the given address notation.
    - ***Usage scenario****:* A database developer cleanses a production database, by matching its existing address data with the address data in the address registers of the linked data infrastructure.
    - ***Usage scenario****:* A citizen declares an address change at the civil registry of his municipality. The system requires the user to disambiguate the address data. The official request contains an address identifier, rather than an address notation.

- **Use Case 2: Look up** (de-reference) address identifiers in different formats. A *human user* looks-up further information about an address identifier by entering it – an HTTP URI – in the address bar of his browser. The system returns a webpage with all information it can share with this user about this address. Similarly, a *machine user* sends an HTTP request with request URL the given HTTP URI of the address and indicates the desired response format (e.g. RDF-XML or JSON notation). The system returns machine-readable information about the address in the format requested.
    - ***Usage scenario:*** A human user wants to verify that he uses the correct address identifier. He enters the HTTP URI in his browser and verifies whether the information returned is correct. He uses the links contained in the response to explore related information resources.
    - ***Usage scenario:*** A programmer working for the Brussels public transport organisation wants to obtain both the official French and Dutch writings of all address objects within a client dataset. She writes a small JavaScript that obtains the desired information for each address object in the dataset by dereferencing the address URIs.

- **Use Case 3: Link** data sets via unique address identifiers. This use case is a consequence of using *common* address identifiers (preferably HTTP URIs) to denote addresses.
    - ***Usage scenario:*** Two public administrations want to join up two datasets on the basis of obtained address information. This is possible without data cleansing, because both datasets use common address identifiers to denote addresses. This situation is depicted in Figure 6.

e.g. tax administration	
Watermaal-Bosvoorde, Aartshertogenl., 34	http://location.testproject.eu /so/ad/Address/CIRB/1228305
Watermaal-Bosvoorde, Aartshertogenlaan, 36	http://location.testproject.eu /so/ad/Address/CIRB/1228228
Watermael-Boitsfort, Av. des Archiducs, 40	http://location.testproject.eu /so/ad/Address/CIRB/1228226
Hoeilaart, Brusselsesteenweg, 87	http://location.testproject.eu /so/ad/Address/AGIV/2000008168
… …	… …

e.g. social security administration	
http://location.testproject.eu /so/ad/Address/CIRB/1228305	Watermael-Boitsfort, Av. des Archiducs, 34
http://location.testproject.eu /so/ad/Address/CIRB/1228228	Watermaal-Bosvoorde, Aartshertogenl., 36
http://location.testproject.eu /so/ad/Address/CIRB/1228226	Watermaal-Bosvoorde, Aartshertogenl., 40
http://location.testproject.eu /so/ad/Address/AGIV/2000008168	Hoeilaart, Brusselsestw. 87
… …	… …

Figure 6 –The use of URIs as common identifiers allow *linking* datasets (Use Case 3)

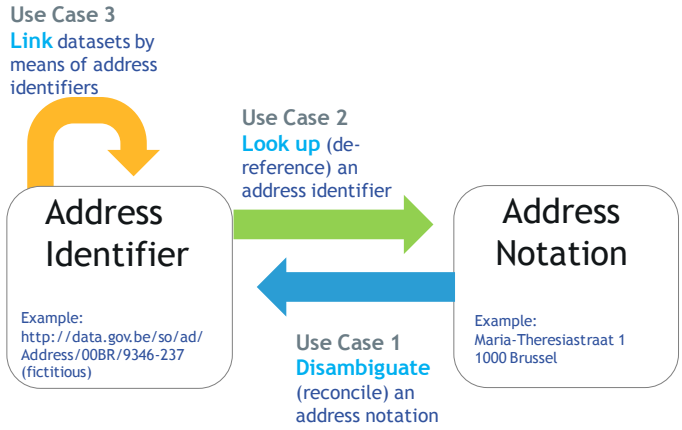


Figure 7 – Target uses cases: disambiguate, lookup, and link

1.8 Targeted benefits

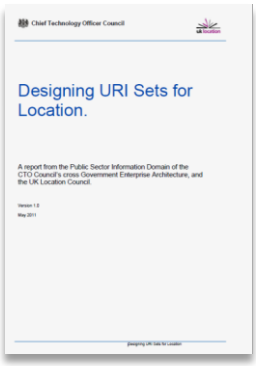
This pilot aims at *demonstrating* the following potential benefits both to data publishers and data consumers (public administrations and businesses).

- The use of the Core Location Vocabulary and URIs as common identifiers make fragmented and heterogeneous general Belgian address data **interoperable** and **linkable**;
- The use of standard Web interfaces (such as HTTP(S)) and query protocols (SPARQL) can greatly **simplify the use of location data**.
- An increased use of address and location data might lead to **improved quality** of address data, e.g. by crowd-sourcing improvements to data quality.
- Possibility to develop **new data-driven services and applications**, thus creating value and ROI from the data.
- Capitalise on this rich space of semantically-interoperable linked core location data in order to **deliver (cross-border) public services more efficiently**.

The Dutch Government has a publication on 'reaping the benefits' of opening up its address and building register [BAG]. It describes a number of business cases, including among others:

- Emergency services
- Law enforcement
- Environmental licensing
- Postal services
- Property tax
- Cadastre
- Utilities

2 URI sets for Belgian address data



This section contains a description of the URI sets for Belgian address data used in the context of this pilot. It is based on the INSPIRE conceptual model [INSPIRE D2.5] and the 2011 report of the British Chief Technology Officer Council entitled 'Designing URI Sets for Location'. The INSPIRE conceptual model allows for the interoperability of identifying systems for spatial objects based on *namespaces*, *local identifiers*, and *version ids*. The report 'Designing URI Sets for Location' incorporates the notion of INSPIRE object identifiers and defines a URI template for INSPIRE spatial things and objects.

For the purpose of this pilot, URI sets of spatial things and corresponding information resources have the following form:

- **Spatial thing**: http://{domain.name}/id/{type}/{namespace}/{localId}
- **Information resource**: http://{domain.name}/doc/{type}/{namespace}/{localId}

The same address may have different abstractions or views on the structure of the same entity. For example, an address as a spatial thing may be represented using the INSPIRE Address Specification or the UPU S42 address template [UPU]. URI sets of spatial objects and corresponding information resources have the following form:

- **Spatial object**: http://{domain.name}/so/{theme}/{class}/{namespace}/{localId}
- **Information resource**: http://{domain.name}/doc/{theme}/{class}/{namespace}/{localId}

URI sets for geometries and corresponding information resources are structured as follows:

- **Geometry**: http://{domain.name}/id/geometry/{namespace}/{localId}
- **Information resource**: http://{domain.name}/doc/geometry/{namespace}/{localId}

Table 4 provides further description for each constituent part – called URI template field.

Table 4 – Path structure for location URIs [LocationURI]

URI template field	Description
{domain.name}[3]	The proposed domain name on which address data is stored. Ideally, this domain name is not linked to an individual organisation whose name is prone to changes. For the purpose of this pilot, the domain name 'testproject.eu' was carefully chosen, precisely because it indicates that this domain name is not intended to be permanent. **Examples**: location.gov.be

[3] Note: for the purpose of the pilot, the domain namespace '**http://location.testproject.eu/BEL/**' will be used. This domain name is only a temporary, the URIs will not persist.

{theme}	A two letter code for the corresponding INSPIRE theme – see Annex II of [LocationURI].
{type}	The typology of the spatial thing.
{class}	The INSPIRE conceptual model class name corresponding to the most specific (leaf-level) feature-type used in expressing a spatial-object or in abstracting a spatial-thing. By convention class names begin with an uppercase letter to distinguish them from property names [LocationURI].
{namespace}	The namespace component of an INSPIRE Unique Object Identifier. It is intended as a unique identifier prefix to enable delegated administration of local identifier within a framework of globally unique identifiers [INSPIRE]. The namespace value will be owned by the data provider of the spatial object and will be registered in the INSPIRE External Object Identifier Namespaces Register [INSPIRE D2.5].
{localId}	The localId component of an INSPIRE Unique Object Identifier. It is the responsibility of the data provider to guarantee uniqueness of the local identifier within the namespace
{version}	The versionId component of an INSPIRE Unique Object Identifier.

The following tables enumerate the values used for each URI template field.

Table 5 – Code list for {theme} [INSPIRE]

Code	Description
ad	INSPIRE Addresses Vocabulary
au	INSPIRE Administrative Units Vocabulary
cp	INSPIRE Cadastral Parcels
ic	INSPIRE Common Model Vocabulary
net	INSPIRE Networks Vocabulary
rs	INSPIRE Coordinate Reference System
tn	INSPIRE Transport Networks Vocabulary
tnro	INSPIRE Road Transport Networks Vocabulary

Table 6 – Code list for {class} [INSPIRE]

INSPIRE Class	Description
Address	An identification of the fixed location of property by means of a structured composition of geographic names and identifiers.
AddressRepresentation	Representation of an address spatial object for use in external application schemas that need to include the basic address information in a readable way.
AdministrativeUnit	Unit of administration where a Member State has and/or exercises jurisdictional rights, for local, regional and national governance.
Road	A collection of road link sequences and/or individual road links that

	are characterized by one or more thematic identifiers and/or properties.-- Description --EXAMPLE Examples are roads characterized by a specific identification code, used by road management authorities or tourist routes, identified by a specific name.

Table 7 – Code list for {namespace} [Organisation]

Namespace code	Description
AGIV	experimental INSPIRE namespace for AGIV.
BPOST	experimental INSPIRE namespace for BPOST.
CIRB	experimental INSPIRE namespace for CIRB.
NGI	experimental INSPIRE namespace for NGI.
RN	experimental INSPIRE namespace for the Civil Register.
SPW	experimental INSPIRE namespace for SPW.
STATBEL	experimental INSPIRE namespace for DGSEI.

Table 8 – Sample URIs

Concept	Sample URI
Address (spatial thing)	http://location.testproject.eu/id/address/AGIV/2000017467 http://location.testproject.eu/id/address/CIRB/1232998 http://location.testproject.eu/id/address/SPW/451463
Address (spatial object)	http://location.testproject.eu/so/ad/Address/AGIV/2000017467 http://location.testproject.eu/so/ad/Address/CIRB/1232998 http://location.testproject.eu/so/ad/Address/SPW/451463
PostalDescriptor (spatial object)	http://location.testproject.eu/so/ad/PostalDescriptor/BPOST/1560
AddressLocator (spatial object)	http://location.testproject.eu/so/AddressLocator/AGIV/2000017467
Address-Representation (spatial object)	http://location.testproject.eu/so/ad/AddressRepresentation/AGIV/2000017467 http://location.testproject.eu/so/ad/AddressRepresentation/CIRB/1232998 http://location.testproject.eu/so/ad/AddressRepresentation/SPW/451463
Administrative-Unit (spatial thing)	http://location.testproject.eu/id/administrative-unit/STATBEL/24000
Administrative-Unit (spatial object)	http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/24000
Road (spatial thing)	http://location.testproject.eu/id/road/RN/15601625
Road (spatial object)	http://location.testproject.eu/so/tn/Road/RN/10005081

3 Mapping the sample datasets to the Core Location Vocabulary

This section contains a description of the sample datasets and a mapping to the Core Location RDF Vocabulary v1.00. The provided sample dataset contains information about the following municipalities:

Table 9 – Municipalities covered by the sample datasets

Municipality	Region	Data provider
Watermael-Boitsfort Watermaal-Bosvoorde	Brussels Region	CIRB, NGI, DGSEI
La Hulpe / Terhulpen	Walloon Region	SPW, NGI, DGSEI
Hoeilaart / Hoeilaart	Flemish Region	AGIV, NGI, DGSEI

We have selected these municipalities as they are bordering municipalities each situated in a different administrative region, such that address data is maintained and is published by three separate organizations.

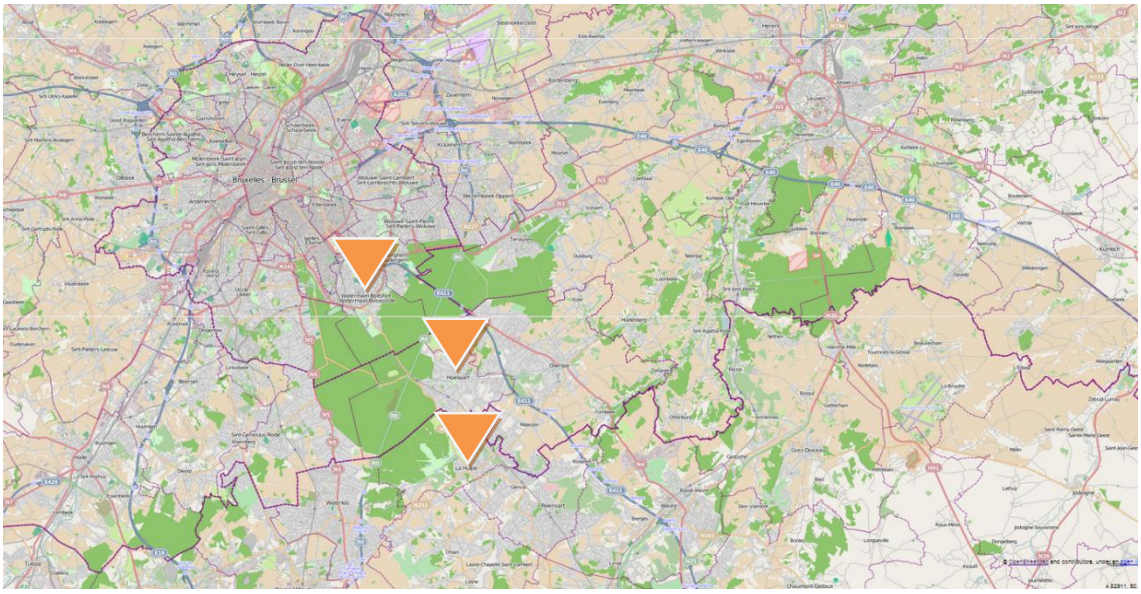


Figure 8 – The sample datasets cover Watermael-Boitsfort, Hoeilaart, and La Hulpe [OSM]

The remainder of the text assumes some familiarity of the reader with the RDF data model. The reader is referred to the RDF Primer [RDFPrimer] for an overview.

3.1 DGSEI – DG Statistics and Economic information

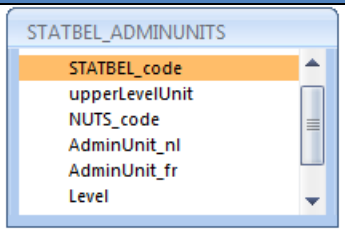
The Belgian national institute for statistics maintains a code list for administrative units[4] [Admin-Geo] at the five levels: municipalities, boroughs, provinces, regions, and the national level. EuroStat's Nomenclature of territorial units for statistics [NUTS] also contains similar code lists until the level of the borough. Both datasets were manually joined up using a spreadsheet. Table 10 contains a sample of the data. Table 11 shows how the dataset was mapped to the Core Location Vocabulary. It contains a representation of the relational database structure, the mappings to RDF Subject-Predicate-Object triples, and a sample turtle file.

Table 10 – Administrative units: sample data

STATBEL_code	upperLevelUnit	NUTS_code	AdminUnit_nl	AdminUnit_fr	Level
1000		BE	België	Belgique	1
2000	1000	BE2	Vlaams Gewest	Région Flamande	2
3000	1000	BE3	Waals Gewest	SPW	2
4000	1000	BE1	Brussels Hoofdstedelijk Gewest	Région de Bruxelles-Capitale	2
10000	2000	BE21	Provincie Antwerpen	Province d'Anvers	3
11000	10000	BE211	Arrondissement Antwerpen	Arrondissement d'Anvers	4
11001	11000	BE212	Aartselaar	Aartselaar	5
11002	11000	BE213	Antwerpen	Anvers	5
...	...	...	...	...	...

Table 11 – Administrative units: mapping table

Relational data structure



Relational-to-RDF mapping

Subject	Predicate	Object
STATBEL_code – URI `a au:AdministrativeUnit`	`au:NUTS`	**NUTS_code** – URI `a au:NUTSRegion`
	`au:upperLevelUnit`	**upperLevelUnit** – URI

[4]Directorate-general Statistics and Economic information (DGSEI)I, Dataset for Administrative Geography: http://statbel.fgov.be/nl/statistieken/gegevensinzameling/nomenclaturen/admin-geo/

	locn:geographicName	**AdminUnit_nl** @nl
	locn:geographicName	**AdminUnit_fr** @fr
	au:nationalLevel	**Level** – URI (skos:Concept in scheme au:AdministrativeHierarchyLevel)

Sample RDF data (turtle syntax)

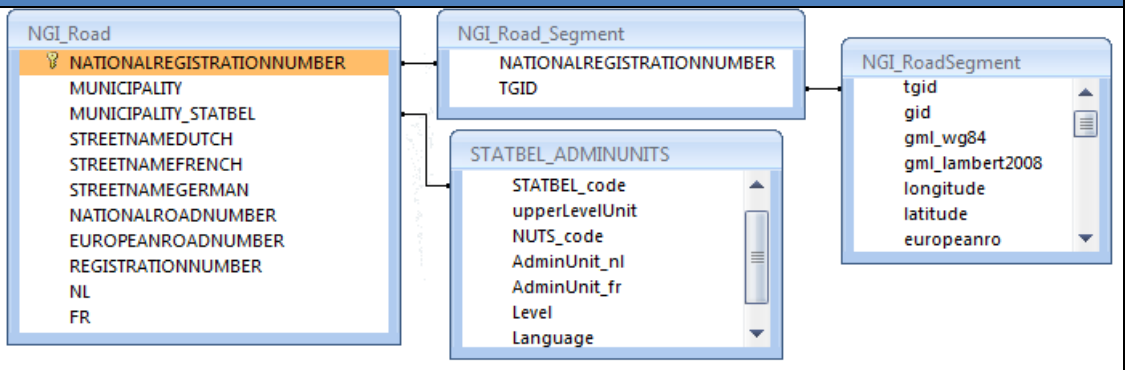
```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix locn: <http://www.w3.org/ns/locn#> .
@prefix ic: <http://inspire.ec.europa.eu/def/ic/> .
@prefix au: <http://inspire.ec.europa.eu/def/au/> .

<http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/21017>
       rdf:type au:AdministrativeUnit ;
       au:upperLevelUnit
<http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/21000> ;
       locn:geographicName "Watermaal-Bosvoorde"@nl , "Watermael-Boitsfort"@fr ;
       au:nationalLevel <http://inspire.ec.europa.eu/def/code-
list/AdministrativeHierarchyLevel/5thOrder> .

<http://location.testproject.eu/doc/au/AdministrativeUnit/STATBEL/21017>
       rdf:type foaf:Document ;
       dcterms:creator <http://statbel.fgov.be/en/statistics/organisation/> ;
       dcterms:rightsHolder <http://statbel.fgov.be/en/statistics/organisation/> ;
       dcterms:conformsTo <http://inspire.ec.europa.eu/spec/au> ;
       foaf:primaryTopic
<http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/21017> ;
       dcterms:hasFormat
       <http://location.testproject.eu/doc/au/AdministrativeUnit/STATBEL/21017.rdf> ,
       <http://location.testproject.eu/doc/au/AdministrativeUnit/STATBEL/21017.xml> .

<http://location.testproject.eu/doc/administrative-unit/STATBEL/21017>
       rdf:type foaf:Document ;
       dcterms:creator <http://statbel.fgov.be/en/statistics/organisation/> ;
       dcterms:rightsHolder <http://statbel.fgov.be/en/statistics/organisation/> ;
       foaf:primaryTopic <http://location.testproject.eu/id/administrative-
unit/STATBEL/21017> ;
       dcterms:hasFormat
<http://location.testproject.eu/doc/administrative-unit/STATBEL/21017.html> ,
<http://location.testproject.eu/doc/administrative-unit/STATBEL/21017.rdf> .

<http://location.testproject.eu/id/administrative-unit/STATBEL/21017>
       skos:prefLabel "Watermael-Boitsfort"@fr ;
       rdfs:seeAlso
<http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/21017> .
```

3.2 NGI – National Geographic Institute

The ITGI database of the NGI contains among other things geometric road segment information enriched with additional information, including the road identifier maintained by the National Civil Register. The road segments were provided in shape format using the national Lambert 2008 projection. We have converted the shape file 'RO_RoadSegmentWithStreetname.shp' into a relational structure using PostGis' shp2sql application. Afterwards, the data were further normalised into three distinct tables. For each road segment, the geometry was reduced to the centroid of the polygon using PostGis. Table 12 depicts the relational data structure, the mapping to the Core Location RDF Vocabulary, and an example dataset.

Table 12 – ITGI road segments: relational data structure

Relational data structure



Relational-to-RDF mapping

Subject	Predicate	Object
NGI_Road.NATIONALREGISTRATION-NUMBER – URI a tnro:Road	ic:admUnit	**MUNICIPALITY_STATBEL** – URI
	locn:geographicName	**STREETNAMEDUTCH** @nl
	locn:geographicName	**STREETNAMEFRENCH** @fr
	locn:geographicName	**STREETNAMEGERMAN** @de
	locn:geometry	**TGID**
	ic:nationalCode	**NATIONALROADNUMBER**
	tnro:europeanRouteNumber	**EUROPEANROUTENUMBER**

Sample RDF data (turtle syntax)

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
```

```
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix locn: <http://www.w3.org/ns/locn#> .
@prefix ic: <http://inspire.ec.europa.eu/def/ic/> .
@prefix tnro: <http://inspire.ec.europa.eu/def/tn-ro/> .
@prefix au: <http://inspire.ec.europa.eu/def/au/> .

<http://location.testproject.eu/so/tn/Road/RN/15601625>
       rdf:type tnro:Road ;
       ic:admUnit
<http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/23033> ;
       locn:geographicName "Terhulpsesteenweg"@nl .
       <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/23033>
       rdf:type au:AdministrativeUnit ;
       locn:geographicName "Hoeilaart"@nl .

<http://location.testproject.eu/doc/tn/Road/RN/15601625>
       rdf:type foaf:Document ;
       dcterms:creator <http://www.ngi.be/FR/FR3-1-1> ;
       dcterms:rightsHolder <http://www.ngi.be/FR/FR3-1-1> ;
       dcterms:conformsTo <http://inspire.ec.europa.eu/spec/tn-ro> ;
       foaf:primaryTopic <http://location.testproject.eu/so/tn/Road/RN/15601625> ;
       dcterms:hasFormat
<http://location.testproject.eu/doc/tn/Road/RN/15601625.rdf> ,
<http://location.testproject.eu/doc/tn/Road/RN/15601625.xml> .

<http://location.testproject.eu/id/road/RN/15601625>
       skos:prefLabel "Terhulpsesteenweg"@nl ;
       rdfs:seeAlso <http://location.testproject.eu/so/tn/Road/RN/15601625> .

<http://location.testproject.eu/doc/road/RN/15601625>
       rdf:type foaf:Document ;
       dcterms:creator <http://www.ngi.be/FR/FR3-1-1> ;
       dcterms:rightsHolder <http://www.ngi.be/FR/FR3-1-1> ;
       foaf:primaryTopic <http://location.testproject.eu/id/road/RN/15601625> ;
       dcterms:hasFormat
<http://location.testproject.eu/doc/road/RN/15601625.html> ,
<http://location.testproject.eu/doc/road/RN/15601625.rdf> .
```

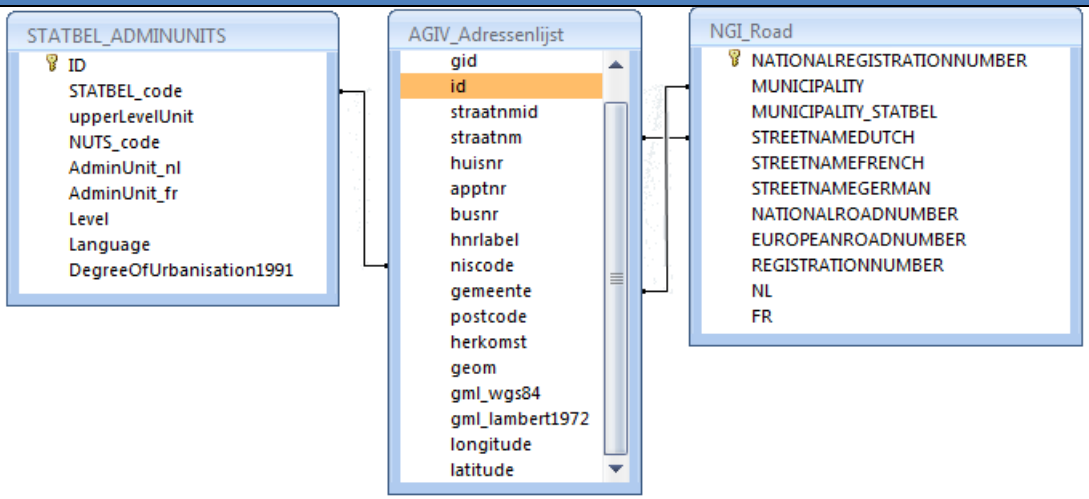
3.3 AGIV – Address Data of the Flemish Region

AGIV (Agentschap voor Geografische Informatie Vlaanderen) maintains the Flemish address register 'CRAB' (Centraal Referentie Adressen Bestand) in close collaboration with the municipalities. On June 1st 2011, CRAB became the first to be recognised as an authentic geographical data source by the Flemish government. Since June 2012, the Flemish Government (Belgium) also has opened up its address and building register (CRAB) for commercial purposes[5].

From the CRAB address register the dataset 'CRAB Addressenlijst'[6] was provided for the whole Flemish Region in Esri shape format. The shapefile was imported into PostGIS and filtered only to contain data for the municipality of Hoeilaart. PostGIS was also used to add some derived geometries, such as the GML notation and WGS84 latitude-longitude coordinates. The filtered data was uploaded to OpenLink Virtuoso in a relational data format and mapped to the Core Location RDF Vocabulary as described in Table 13. The data was linked to the administrative units maintained by the Belgian National Institute for Statistics and the road register provided by the NGI.

Table 13 – AGIV: relational table and mapping to the Core Location Vocabulary

Relational data structure



Relational-to-RDF mapping

Subject	Predicate	Object
id – URI a locn:Address a ad:Address	ic:adminUnit	**niscode** – URI
	tnro:road	**NATIONALREGISTRATION-NUMBER** – URI
	locn:geometry	**id** – URI

[5] 2012-06-01, commercial reuse of CRAB free of charge, http://www.agiv.be/gis/nieuws/?artid=1715

[6] CRAB Addressenlijst, http://metadata.agiv.be/Details.aspx?fileIdentifier=6ef348e1-69eb-4cad-8ccd-1c68099afcf3

	locn:fullAddress	**straatnm + huisnr + 'bus' + busnr** **postcode + gemeente** @nl
	locn:postCode	**postcode**
	locn:postName	**gemeente** @nl
	locn:thoroughfare	**straatnm** @nl
	locn:locatorDesignator	**huisnr**
	locn:locatorDesignator	**huisnrlabel**
	locn:locatorDesignator	'bus'+ **apptnr**
	locn:locatorDesignator	'bus'+ **busnr**
	locn:adminUnitL5	**gemeente** @nl
	locn:adminUnitL4	' Arrondissement Halle-Vilvoorde' @nl
	locn:adminUnitL3	'Provincie Vlaams-Brabant' @nl
	locn:adminUnitL2	'Vlaams Gewest' @nl
	locn:adminUnitL1	'België' @nl
id - URI a locn:Geometry	geo:lat schema:latitude	**latitude**
	geo:long schema:longitude	**longitude**
	ogc:asGMLLiteral	**gml_lambert1972**
	ogc:asGMLLiteral	**gml_wg84**

Sample RDF data (turtle syntax)

```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix ogc: <http://www.opengis.net/rdf#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix schema: <http://schema.org/> .
@prefix locn: <http://www.w3.org/ns/locn#> .
@prefix ic: <http://inspire.ec.europa.eu/def/ic/> .
@prefix au: <http://inspire.ec.europa.eu/def/au/> .
@prefix ad: <http://inspire.ec.europa.eu/def/ad/> .
```

```
<http://location.testproject.eu/id/address/AGIV/2000017467>
        rdfs:seeAlso    <http://location.testproject.eu/so/ad/Address/AGIV/2000017467> ,
        <http://location.testproject.eu/so/ad/AddressRepresentation/AGIV/2000017467> ;
        skos:prefLabel "Terhulpsesteenweg 5 1560 Hoeilaart"@nl ;
        dcterms:hasFormat
        <http://location.testproject.eu/doc/address/AGIV/2000017467.html> ,
        <http://location.testproject.eu/doc/address/AGIV/2000017467.rdf> .

<http://location.testproject.eu/doc/address/AGIV/2000017467>
        rdf:type        foaf:Document ;
        rdfs:comment    "© AGIV 2012. All rights reserved"@en .
        dcterms:rightsHolder  <http://www.agiv.be/gis/organisatie/> ;
        dcterms:creator       <http://www.agiv.be/gis/organisatie/> ;
        foaf:primaryTopic
        <http://location.testproject.eu/id/address/AGIV/2000017467> .

<http://location.testproject.eu/so/ad/Address/AGIV/2000017467>
        rdf:type        ad:Address .
        locn:geometry  <http://location.testproject.eu/id/geometry/AGIV/2000017467> .
        ad:locator
        <http://location.testproject.eu/so/AddressLocator/AGIV/2000017467> ;
        ad:component
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/2000> ,
        <http://location.testproject.eu/so/tn/Road/RN/15601625> ,
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/1000> ,
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/23033> ,
        <http://location.testproject.eu/so/ad/PostalDescriptor/BPOST/1560> .

<http://location.testproject.eu/doc/ad/Address/AGIV/2000017467>
        rdf:type        foaf:Document .
        rdfs:comment    "© AGIV 2012. All rights reserved"@en .
        dcterms:rightsHolder  <http://www.agiv.be/gis/organisatie/> ;
        dcterms:creator       <http://www.agiv.be/gis/organisatie/> .
        dcterms:conformsTo    inspire-spec:ad ;
        foaf:primaryTopic
        <http://location.testproject.eu/so/ad/Address/AGIV/2000017467> .

<http://location.testproject.eu/so/AddressLocator/AGIV/2000017467>
        rdf:type        ad:AddressLocator .
        ad:level        ns2:siteLevel ;
        ad:designator
        <http://location.testproject.eu/so/AddressDesignator/AGIV/20000174675> .

<http://location.testproject.eu/so/AddressDesignator/AGIV/20000174675>
        rdf:type        ad:LocatorDesignator ;
        dcterms:type
        <http://inspire.ec.europa.eu/def/codelist/LocatorDesignatorTypeValue:buildingId>
;
        locn:locatorDesignator        "5" .

<http://location.testproject.eu/so/ad/PostalDescriptor/BPOST/1560>
        rdf:type        ad:PostalDescriptor ;
        locn:postCode  1560 ;
        locn:postName  "Hoeilaart"@nl .

<http://location.testproject.eu/so/ad/AddressRepresentation/AGIV/2000017467>
```

```
        rdf:type        locn:Address ;
        locn:geometry   <http://location.testproject.eu/id/geometry/AGIV/2000017467> .
        locn:postCode   1560 ;
        locn:thoroughfare       "Terhulpsesteenweg"@nl ;
        locn:adminUnitL1        "België"@nl ;
        locn:adminUnitL2        "Vlaams Gewest"@nl ;
        locn:adminUnitL3        "Provincie Vlaams-Brabant"@nl ;
        locn:adminUnitL4        "Arrondissement Halle-Vilvoorde"@nl ;
        locn:adminUnitL5        "Hoeilaart"@nl ;
        locn:fullAddress        "Terhulpsesteenweg 5 1560 Hoeilaart"@nl ;
        locn:locatorDesignator"5"^^ LocatorDesignatorTypeValue:buildingId ;
        ic:adminUnit
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/23033> ;
        ad:transportLink        <http://location.testproject.eu/so/tn/Road/RN/15601625> ;
        locn:postName   "Hoeilaart"@nl ;
        ad:addressFeature
        <http://location.testproject.eu/so/ad/Address/AGIV/2000017467> .

<http://location.testproject.eu/doc/ad/AddressRepresentation/AGIV/2000017467>
        rdf:type        foaf:Document ;
        rdfs:comment    "\u00A9 AGIV 2012. All rights reserved"@en .
        dcterms:rightsHolder    <http://www.agiv.be/gis/organisatie/> ;
        dcterms:creator         <http://www.agiv.be/gis/organisatie/> ;
        dcterms:conformsTo      locn: .
        dcterms:conformsTo      inspire-spec:ad ;
        foaf:primaryTopic
        <http://location.testproject.eu/so/ad/AddressRepresentation/AGIV/2000017467> .

<http://location.testproject.eu/id/geometry/AGIV/2000017467>
        rdf:type        locn:Geometry .
        geo:lat                 "50.7646"^^xsd:float ;
        geo:long                "4.45029"^^xsd:float .
        schema:latitude         "50.7646"^^xsd:float ;
        schema:longitude        "4.45029"^^xsd:float .
        ogc:asGMLLiteral
"<gml:Point
srsName=\"http://www.opengis.net/def/crs/EPSG/0/31370\"><gml:coordinates>155752.75,1615
75.4</gml:coordinates></gml:Point>" ,
"<gml:Point
srsName=\"http://www.opengis.net/def/crs/EPSG/0/4326\"><gml:coordinates>4.45029,50.7646
5</gml:coordinates></gml:Point>" .

<http://location.testproject.eu/doc/geometry/AGIV/2000017467>
        rdf:type        foaf:Document .
        rdfs:comment    "\u00A9 AGIV 2012. All rights reserved"@en .
        dcterms:rightsHolder    <http://www.agiv.be/gis/organisatie/> ;
        dcterms:creator         <http://www.agiv.be/gis/organisatie/> ;
        dcterms:conformsTo      locn: ;
        foaf:primaryTopic
        <http://location.testproject.eu/id/geometry/AGIV/2000017467> .
```

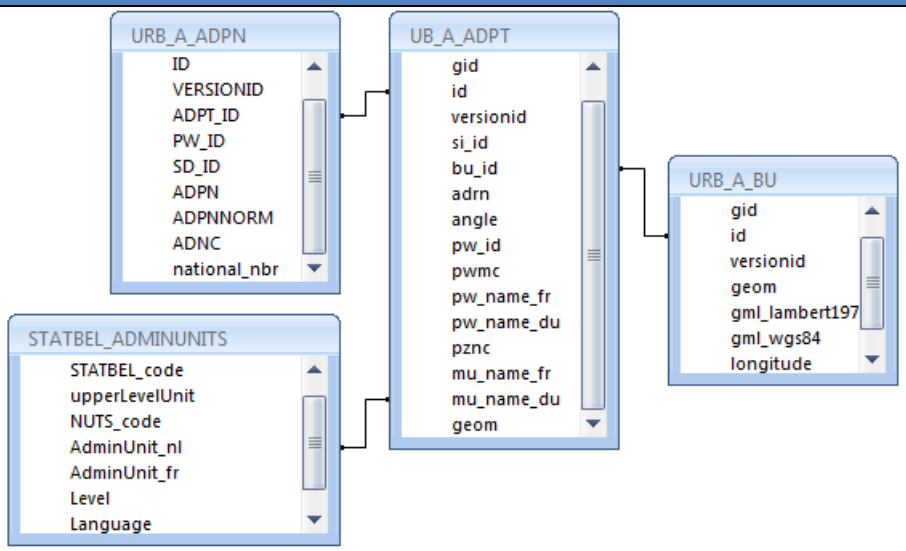
Known limitations:

- **No authentic link with national road register:** the provided sample data does not contain the road identifiers maintained by the national civil register (also present in the NGI ITGI database). To establish a link for the purpose of the pilot, an inferior join condition was used based on the street name.

3.4 CIRB – Address Data of the Brussels Region

CIRB, the IT department of the Brussels Region, maintains the UrbIS-Adm geospatial database which contains the main administrative divisions of the territory of the Brussels-Capital Region. The dataset was obtained in several formats and contained all of Brussels-Capital Region, however to acquire derived geometries, for instance the GML notation and WGS84 (latitude and longitude), we imported the shapefiles using PostGIS and transformed the geometries. After this a portion of the data, relating to address and municipality of Watermael-Boitsfort, was imported and mapped to the Core Location RDF Vocabulary in a similar manner to AGIV. The mapping to the Core location of the CIRB data is described beneath in Table 9. Then the data was linked with the existing information provided by the Belgian National Institute for Statistics.

Table 14 – URBIS : relational table and mapping to the Core Location Vocabulary

Relational data structure


Relational-to-RDF mapping		
Subject	**Predicate**	**Object**
URB_A_ADPT.id - URI a locn:Address	ic:adminUnit	**statbel_code_iri** - URI
	locn:geometry	**bu_id**
	locn:locatorDesignator	**adrn**
	locn:thoroughfare	**pw_name_fr** @fr
	locn:thoroughfare	**pw_name_du** @nl
	locn:postCode	**pznc**
	locn:adminUnitL5	**mu_name_fr** @fr

	locn:adminUnitL5	**mu_name_du** @nl
	locn:fullAddress	**mu_name_fr**+ **pw_name_du** + **adrn** @fr
	locn:fullAddress	**mu_name_du** + **pw_name_du** + **adrn** @nl
URB_A__BU.ID - URI a locn:Geometry	geo:lat schema:latitude	**latitude**
	geo:long schema:longitude	**longitude**
	ogc:asGMLLiteral	**gml_lambert1972**
	ogc:asGMLLiteral	**gml_wg84**

Sample RDF data (turtle syntax)

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix ogc: <http://www.opengis.net/rdf#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix schema: <http://schema.org/> .
@prefix locn: <http://www.w3.org/ns/locn#> .
@prefix ic: <http://inspire.ec.europa.eu/def/ic/> .
@prefix au: <http://inspire.ec.europa.eu/def/au/> .
@prefix ad: <http://inspire.ec.europa.eu/def/ad/> .

<http://location.testproject.eu/id/address/CIRB/1232998>
        rdf:type        rdfs:Resource ;
        rdfs:seeAlso    <http://location.testproject.eu/so/ad/Address/CIRB/1232998> ,
        <http://location.testproject.eu/so/ad/AddressRepresentation/CIRB/1232998> .
        skos:prefLabel "Chaussée de La Hulpe 266 1170 Watermael-Boitsfort"@fr ,
                "Terhulpsesteenweg 266 1170 Watermaal-Bosvoorde"@nl .

<http://location.testproject.eu/doc/adress/CIRB/1232998>
        rdf:type        foaf:Document .
        foaf:primaryTopic       <http://location.testproject.eu/id/address/CIRB/1232998> .
        rdfs:comment    "Realized by means of Brussels UrbIS ®© - Distribution &
Copyright CIRB."@nl .
        dcterms:rightsHolder    ns4:cartographie-digitale-urbis ;
        dcterms:creator         ns4:cartographie-digitale-urbis .

<http://location.testproject.eu/so/ad/Address/CIRB/1232998>
        rdf:type        ad:Address .
        locn:geometry   <http://location.testproject.eu/id/geometry/CIRB/8732896> .
        ad:locator      <http://location.testproject.eu/so/AddressLocator/CIRB/1232998> ;
        ad:component    <http://location.testproject.eu/so/tn/Road/RN/11702128> ,
        <http://location.testproject.eu/so/ad/PostalDescriptor/BPOST/1170> ,
```

```
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/21017> ,
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/1000> ,
         <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/21000> ,
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/4000> .

<http://location.testproject.eu/so/AddressLocator/CIRB/1232998>
        rdf:type        ad:AddressLocator ;
        ad:level        http://inspire.ec.europa.eu/def/code-
list/LocatorLevelValue/siteLevel ;
        ad:designator
        <http://location.testproject.eu/so/AddressDesignator/CIRB/1232998266> .

<http://location.testproject.eu/so/AddressDesignator/CIRB/1232998266>
        rdf:type        ad:LocatorDesignator ;
        dcterms:type    <http://inspire.ec.europa.eu/def/code-
list/LocatorDesignatorTypeValue/buildingId ;
        locn:locatorDesignator          "266" .

<http://location.testproject.eu/so/ad/PostalDescriptor/BPOST/1170>
        rdf:type        ad:PostalDescriptor .
        locn:postCode   1170 ;
        locn:postName   "Watermael-Boitsfort"@fr ,
                "Watermaal-Bosvoorde"@nl .

<http://location.testproject.eu/so/tn/Road/RN/11702128>
        rdf:type ad:ThoroughfareName ;
        ad:transportLink <http://location.testproject.eu/so/tn/Road/RN/11702128> ;
        locn:geographicName
        "Terhulpsesteenweg"@nl ,
        "Chaussée de La Hulpe"@fr .

<http://location.testproject.eu/so/ad/AddressRepresentation/CIRB/1232998>
        rdf:type        locn:Address ;
        locn:geometry   <http://location.testproject.eu/id/geometry/CIRB/8732896> ;
        locn:postCode   1170 ;
        locn:thoroughfare       "Chaussée de La Hulpe"@fr ,
                "Terhulpsesteenweg"@nl ;
        locn:adminUnitL1        "België"@nl ,
                "Belgique"@fr ;
        locn:adminUnitL2        "Brussels Hoofdstedelijk Gewest"@nl ,
                "Région de Bruxelles-Capitale"@fr ;
        locn:adminUnitL4        "Arrondissement Brussel Hoofdstad"@nl ,
                "Arrondissement de Bruxelles-Capitale"@fr ;
        locn:adminUnitL5        "Watermaal-Bosvoorde"@nl ,
                "Watermael-Boitsfort"@fr ;
        locn:fullAddress        "Terhulpsesteenweg 266 1170 Watermaal-Bosvoorde"@nl ,
                "Chaussée de La Hulpe 266 <br/> 1170 Watermael-Boitsfort"@fr ;
        locn:locatorDesignator"266"^^ LocatorDesignatorTypeValue:buildingId ;
        ic:adminUnit
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/21017> ;
        ad:transportLink        <http://location.testproject.eu/so/tn/Road/RN/11702128> ;
        locn:postName   "Watermael-Boitsfort"@fr ,
                "Watermaal-Bosvoorde"@nl ;
        ad:addressFeature
        <http://location.testproject.eu/so/ad/Address/CIRB/1232998> ;
        rdfs:seeAlso
```

```
        <http://location.testproject.eu/so/ad/AddressRepresentation/CIRB/1232998> .

<http://location.testproject.eu/doc/ad/AddressRepresentation/CIRB/1232998>
        rdf:type        foaf:Document ;
        rdfs:comment    "Realized by means of Brussels UrbIS ®© - Distribution &
Copyright CIRB."@en ;
        dcterms:rightsHolder
        http://www.cirb.irisnet.be/dienstencatalogus/urbis/cartographie-digitale-urbis ;
        dcterms:conformsTo      inspire-spec:ad ,
                locn: ;
        foaf:primaryTopic
        <http://location.testproject.eu/so/ad/AddressRepresentation/AGIV/1232998> .


<http://location.testproject.eu/id/geometry/CIRB/8732896>
        dcterms:rightsHolder  ns5:cartographie-digitale-urbis .
        geo:lat "50.7921"^^xsd:float ;
        geo:long        "4.4209"^^xsd:float ;
        schema:latitude         "50.7921"^^xsd:float ;
        schema:longitude        "4.4209"^^xsd:float ;
        ogc:asGMLLiteral        "<gml:Point
srsName=\"http://www.opengis.net/def/crs/EPSG/0/4326\"><gml:coordinates>4.4209,50.7921<
/gml:coordinates></gml:Point>" ,
                "<gml:Point
srsName=\"http://www.opengis.net/def/crs/EPSG/0/31370\"><gml:coordinates>153677.15187,1
64627.19681</gml:coordinates></gml:Point>" .

<http://location.testproject.eu/doc/geometry/CIRB/8732896>
        dcterms:rightsHolder
        <http://www.cirb.irisnet.be/dienstencatalogus/urbis/cartographie-digitale-
urbis>;
        dcterms:conformsTo      locn: ;
        foaf:primaryTopic       <http://location.testproject.eu/id/geometry/CIRB/8732896>.
```

Known limitations:

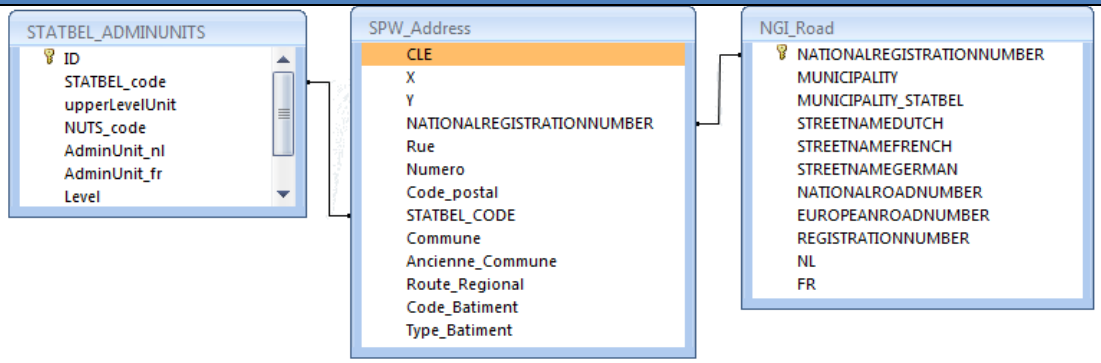
- **No fine-grained locator designator data**: the provided sample data does not contain fine-grained locator designators, that could help address problems related to “complex numbering” as introduced in Section 1.4.

3.5 SPW – Address Data of the Walloon Region

The Wallonia Public Service (SPW) maintains a geospatial database in the context of its PICC project (Projet Informatique de Cartographie Continue). From this system, a sample of address data was provided in the format of a spreadsheet for the municipality of “La Hulpe”. The spreadsheet was enriched with additional data: the known road numbers maintained by the Civil Register, and the code for the municipality of La Hulpe, as given by the national institute for statistics (DGSEI). The spreadsheet was imported into PostGis, and the X and Y coordinates (using a Lambert 1972 project) were transformed into GML notation and WGS84 Latitude/Longitude Coordinates using PostGIS. Afterwards, a relational table was uploaded to OpenLink Virtuoso. Table 15 contains a representation of the relational database structure, the mappings to RDF Subject-Predicate-Object triples, and a sample turtle file.

Table 15 – SPW: relational table and mapping to the Core Location Vocabulary

Relational data structure



Relational-to-RDF mapping

Subject	Predicate	Object
CLE – URI a locn:Address	ic:adminUnit	**MUNICIPALITY_STATBEL** – URI
	locn:geometry	**CLE** – URI
	locn:fullAddress	**Commune** + **Rue** + **Numero** @fr
	locn:thoroughfare	**Rue** @fr
	ad:transportLink	**NATIONALREGISTRATIONNUMBER** – URI
	locn:adminUnitL5	**Commune** @fr
	locn:adminUnitL4	'Arrondissement de Nivelles' @fr
	locn:adminUnitL3	'Province du Brabant Wallon' @fr
	locn:adminUnitL2	'Région Wallone' @fr

	locn:adminUnitL1	'Belgique' @fr
	locn:thoroughfare	**STREETNAMEGERMAN** @de
	locn:postCode	**Code_postal**
	locn:postName	**Commune** @fr
	locn:geometry	**TGID**
CLE - URI a locn:Geometry	geo:lat schema:latitude	**latitude**
	geo:long schema:longitude	**longitude**
	ogc:asGMLLiteral	**gml_lambert1972**
	ogc:asGMLLiteral	**gml_wg84**

Sample RDF data (turtle syntax)

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix ogc: <http://www.opengis.net/rdf#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix schema: <http://schema.org/> .
@prefix locn: <http://www.w3.org/ns/locn#> .
@prefix ic: <http://inspire.ec.europa.eu/def/ic/> .
@prefix au: <http://inspire.ec.europa.eu/def/au/> .
@prefix ad: <http://inspire.ec.europa.eu/def/ad/> .

<http://location.testproject.eu/id/address/SPW/451463>
        rdf:type        rdfs:Resource ;
        rdfs:seeAlso    <http://location.testproject.eu/so/ad/Address/SPW/451463> ,
                <http://location.testproject.eu/so/ad/AddressRepresentation/SPW/451463>
        skos:prefLabel "Chaussée de Bruxelles 120 1310 La Hulpe" .

<http://location.testproject.eu/doc/adress/SPW/451463>
        rdf:type foaf:Document ;
        dcterms:creator
<http://cartographie.wallonie.be/NewPortailCarto/index.jsp?page=GenInformationsGeo&node
=11> ;
        dcterms:rightsHolder
<http://cartographie.wallonie.be/NewPortailCarto/index.jsp?page=GenInformationsGeo&node
=11> ;
        foaf:primaryTopic <http://location.testproject.eu/id/address/SPW/451463> ;
        dcterms:hasFormat
                <http://location.testproject.eu/doc/address/SPW/451463.html> ,
                <http://location.testproject.eu/doc/address/SPW/451463.rdf> .
```

```
        rdfs:comment '© SPW 2012. All rights reserved'.

<http://location.testproject.eu/so/ad/Address/SPW/451463>
        rdf:type        ad:Address .
        locn:geometry   <http://location.testproject.eu/id/geometry/SPW/451463> .
        ad:locator      <http://location.testproject.eu/so/AddressLocator/SPW/451463> ;
        ad:component
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/3000> ,
                <http://location.testproject.eu/so/tn/Road/RN/13100025> ,
                <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/25050>
,
                <http://location.testproject.eu/so/ad/PostalDescriptor/BPOST/1310> ,
                <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/1000> ;
;
        ad:addressFeature       <http://location.testproject.eu/so/ad/Address/SPW/451463>.


<http://location.testproject.eu/doc/ad/Address/SPW/451463>
        rdf:type        foaf:Document ;
        rdfs:comment    "© SPW 2012. All rights reserved"@en ;
        dcterms:rightsHolder
        <http://cartographie.wallonie.be/NewPortailCarto/index.jsp> ;
        dcterms:conformsTo      inspire-spec:ad ;
        foaf:primaryTopic       <http://location.testproject.eu/so/ad/Address/SPW/451463>.

<http://location.testproject.eu/so/AddressLocator/SPW/451463>
        rdf:type        ad:AddressLocator ;
        ad:level        http://inspire.ec.europa.eu/def/code-
list/LocatorLevelValue/siteLevel ;
        ad:designator
        <http://location.testproject.eu/so/AddressDesignator/SPW/451463120> .

<http://location.testproject.eu/so/AddressDesignator/SPW/451463120>
        rdf:type        ad:LocatorDesignator ;
        dcterms:type    locatorDesignatorType:addressIdentifierGeneral ;
        locn:locatorDesignator "120" .

<http://location.testproject.eu/so/ad/PostalDescriptor/BPOST/1310>
        rdf:type        ad:PostalDescriptor ;
        locn:postCode   1310 ;
        locn:postName   "La Hulpe"@fr .

<http://location.testproject.eu/so/ad/AddressRepresentation/SPW/451463>
        rdf:type        locn:Address ;
        locn:geometry   <http://location.testproject.eu/id/geometry/SPW/451463> ;
        locn:postCode   1310 ;
        locn:thoroughfare       "Chaussée de Bruxelles"@fr ;
        locn:adminUnitL1        "Belgique"@fr ;
        locn:adminUnitL2        "Région Wallone"@fr ;
        locn:adminUnitL3        "Province du Brabant Wallon"@fr ;
        locn:adminUnitL4        "Arrondissement de Nivelles"@fr ;
        locn:adminUnitL5        "La Hulpe"@fr ;
        locn:fullAddress        "Chaussée de Bruxelles 120 1310 La Hulpe"@fr ;
        locn:locatorDesignator"120"^^locatorDesignatorType:addressIdentifierGeneral ;
        ic:adminUnit
        <http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/25050> ;
        ad:transportLink        <http://location.testproject.eu/so/tn/Road/RN/13100025> ;
```

```
        ad:addressFeature      <http://location.testproject.eu/so/ad/Address/SPW/451463>.

<http://location.testproject.eu/doc/ad/AddressRepresentation/SPW/451463>
        rdf:type        foaf:Document ;
        rdfs:comment    "© SPW 2012. All rights reserved"@en ;
        dcterms:rightsHolder
        <http://cartographie.wallonie.be/NewPortailCarto/index.jsp> ;
        dcterms:conformsTo     locn: ;
        foaf:primaryTopic
        <http://location.testproject.eu/so/ad/AddressRepresentation/AGIV/451463> .
```

Known limitations:

- **No fine-grained locator designator data**: the provided sample data does not contain fine-grained locator designators, that could help address problems related to “complex numbering” as introduced in Section 1.6.

4 Description of the linked data infrastructure

This section contains a description of the publicly accessible linked data infrastructure that has been set up in the context of this pilot to illustrate how the use cases identified in Section 1.7 can be put in practice.

4.1 Mapping relational data to RDF

The infrastructure is based on **OpenLink Virtuoso** [Virtuoso]. This is an open-source middleware and database management system that provides access to relational, RDF, XML, and text-based data. A particularly salient feature of OpenLink Virtuoso are its "Linked Data Views"; it allows defining relational-to-RDF mappings that allow Virtuoso's SPARQL processor to **access the relational database tables *at-run-time* without physical regeneration of RDF Data Sets from SQL Data**. Virtuoso's Linked Data Views make it possible to run a Linked Data infrastructure on top of an existing relational database infrastructure. In addition to this, it is possible to store and manipulate RDF data in Virtuoso's native RDF Quad Store. Figure 9 contains a simplified representation of the relevant parts of Virtuoso's architecture. Other tools that allow accessing relation databases as virtual RDF graphs are listed on the D2RQ [D2RQ] web page and include: D2RQ, MySQL Oracle Spatial and Graph, SPASQL, and Sparqlify. Virtuoso's whitepaper 'Mapping Relational Data to RDF with Virtuoso's RDF Views' [QuadMap] provides further information on this topic.

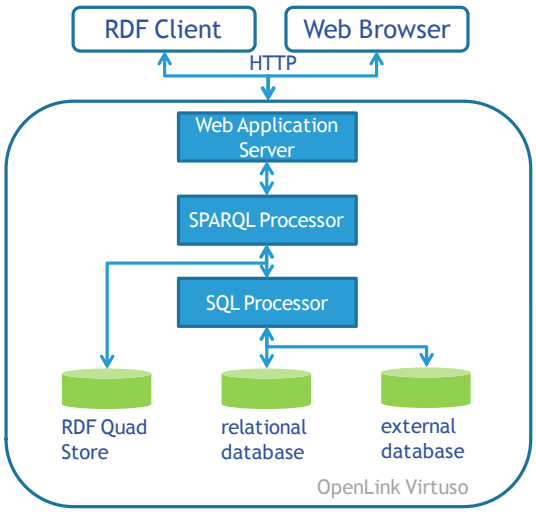


Figure 9 – Virtuoso's Linked Data Views: mapping relational data to RDF

Known limitations:

- **No language tag:** It is currently not (yet) possible to attribute language tags to literals using Virtuoso's Linked Data views.
- **No typed literals:** It is currently not (yet) possible to type literals using Virtuoso's Linked Data views.
- **Character encoding:** We did not succeed in configuring Virtuoso to produce correctly encoded UTF-8 characters.

4.2 Use Case 1 – Disambiguate address notations with SPARQL

The linked data infrastructure deployed for the purpose of this pilot further illustrates the usefulness of the SPARQL interface in providing enhanced access to location data. This might allow both for applications and human end-users to disambiguate a given address notation by attributing a common HTTP URI as identifier (**Use Case 1 – Disambiguate**).

The SPARQL endpoint can be accessed at the following location:
http://location.testproject.eu/sparql

The HTML form at this location can be used to launch for example the following query to the triple store. It searches all addresses, roads, and administrative units in the graph `<http://location.testproject.eu/BEL>` which contain the string `'Watermael-Boitsfort'`.

```
PREFIX locn: <http://www.w3.org/ns/locn#>
PREFIX ex: <http://example.com/>
SELECT DISTINCT ?type ?subject ?label
FROM <http://location.testproject.eu/BEL>
WHERE {
FILTER(?type=locn:Address || ?type=ex:Road || ?type=ex:AdministrativeUnit).
FILTER(?predicate=locn:fullAddress || ?predicate=ex:roadName ||
?predicate=locn:geographicName).
?subject a ?type.
?subject ?predicate ?label.
FILTER(regex(?label,'Watermael-Boitsfort','i')).
}
LIMIT 100
```

This same SPARQL query can also be called from a customised web form, whereby the query results are rendered to HTML format using an appropriate XSLT transformation. This is illustrated in Figure 10. The corresponding web page is available at:
http://location.testproject.eu/BEL/

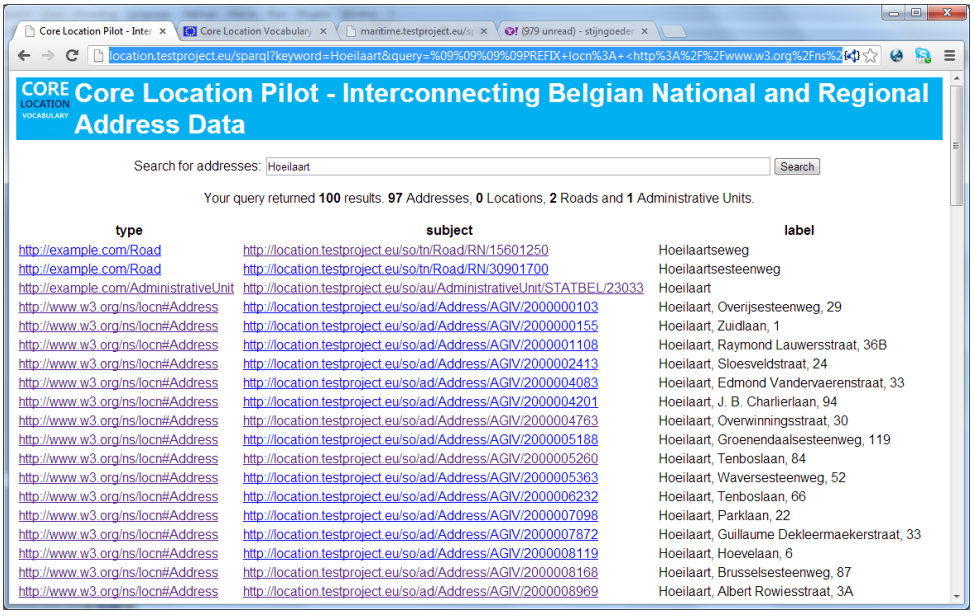


Figure 10 – Screenshot: search for addresses on top of a SPARQL endpoint

Virtuoso's commercial edition also supports a limited set of geospatial extensions to SPARQL. These allow for instance to run SPARQL queries according to the properties of point geometries. The SPARQL query below, for example, selects the top 20 closest locations within maximum 1.0 kilometer of a given location, here <http://location.testproject.eu/so/ad/Address/AGIV/2000271753>.

```
SELECT ?type ?Location bif:st_distance(?geo,?geo2) as ?dist
 FROM <http://location.testproject.eu/BEL>
WHERE {
<http://location.testproject.eu/so/ad/Object/AGIV/2000271753> geo:geometry ?geo.
?Location geo:geometry ?geo2.
?Location a ?type.
FILTER(?geo2 != ?geo).
FILTER(bif:st_distance(?geo,?geo2) < 1.0).
FILTER(!regex(str(?Location),"NGI")).
FILTER(?type = locn:Location).
} ORDER BY ?dist LIMIT 20
```

The result of this query is depicted in Figure 11. The ability to retrieve spatial objects in the vicinity of a given object allow to further distinguish similar objects and therefore contribute to realising Use Case 1

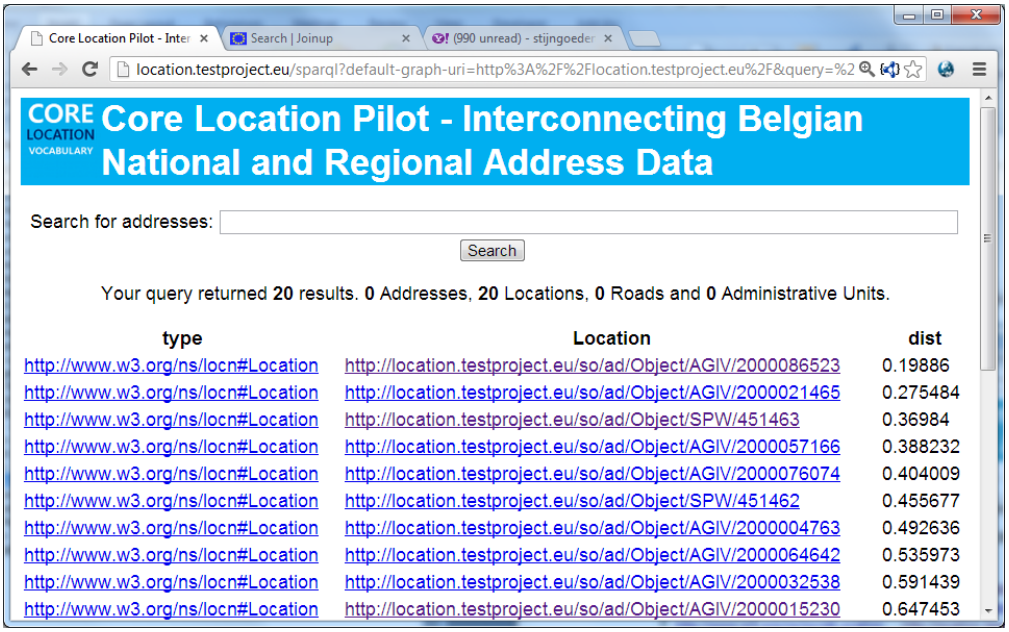


Figure 11 – Screenshot: SPARQL query

4.3 Use Case 2 – Lookup address identifiers through URL rewrite rules

By means of URL rewrite rules, Virtuoso also allows deploying a URI infrastructure that adheres to the *content negotiation* design principles of the HTTP protocol and related design guidelines for Linked Data URIs included in among others the following recommendations: the 2008 W3C Semantic Web Interest Group Note entitled '[Cool URIs for the Semantic Web]' [CoolURIs] and the 2012 study '[10 rules for persistent URIs]' [PURI] developed by the ISA Programme, which are summarised in Figure 12.

Figure 12 – The 10 Dos and DONTs for persistent URIs [PURI]

An essential part of HTTP URIs is that they identify abstract representations of real-world objects. For example, the following URIs identify real-world addresses in the municipalities Hoeilaart, Watermael-Boitsfort, and La Hulpe.

http://location.testproject.eu/**so**/ad/Address/AGIV/2000017467
http://location.testproject.eu/**so**/ad/Address/CIRB/1232998
http://location.testproject.eu/**so**/ad/Address/SPW/451463

The HTTP protocol provides a powerful mechanism – called content negotiation – to allow Web clients (e.g. a Web browser, an RDF application, an e-Government application) for offering different formats of the same Web document known as ***content negotiation***. When de-referenced, URIs that identify real world objects other than Web documents should redirect using HTTP response code 303 to Web documents that describe the object. This should be done in a consistent manner that can be written as a **URI re-write rule**, typically replacing the URI `{type}` of 'so' with 'doc.' In our example, the above mentioned URIs should de-reference to the following URLs:

http://location.testproject.eu/**doc**/ad/Address/AGIV/2000017467.{rendition}
http://location.testproject.eu/**doc**/ad/Address/CIRB/1232998.{rendition}
http://location.testproject.eu/**doc**/ad/Address/SPW/451463.{rendition}

The following HTTP request:

```
GET /so/ad/Address/AGIV/2000017467 HTTP/1.1
```

```
Host: location.testproject.eu
Accept: application/rdf+xml
```

must therefore lead to the following HTTP response with 303 redirect response code:

```
HTTP/1.1 303 See Other
Connection: close
Content-Type: text/html; charset=UTF-8
Date: Mon, 07 Jan 2013 22:23:06 GMT
Accept-Ranges: bytes
Location: http://location.testproject.eu/doc/ad/Address/AGIV/2000017467.rdf
Content-Length: 0
```

Consequently, an RDF client will retrieve the corresponding .rdf document:

```
GET /doc/ad/Address/AGIV/2000017467.rdf HTTP/1.1
Host: location.testproject.eu
Accept: application/rdf+xml
```

Resulting in the desired Web document describing the address object:

```
HTTP/1.1 200 OK
Connection: Keep-Alive
Date: Mon, 07 Jan 2013 22:35:16 GMT
Accept-Ranges: bytes
Content-Type: application/rdf+xml; charset=UTF-8
Content-Length: 1821
```

Figure 13 summarises the aforementioned interaction.

Figure 13 – Interaction diagram: illustration of a HTTP 303 redirection

Via URL rewriting rules, the aforementioned interaction has been implemented in the pilot's linked data infrastructure. The request for resource

```
http://location.testproject.eu/doc/ad/Address/AGIV/2000017467.rdf
```

is internally handled as a SPARQL query

```
DESCRIBE <http://location.testproject.eu/so/ad/Address/AGIV/2000017467>
```

of which the result is returned as an RDF+XML file with the following content:

```
<?xml version="1.0" encoding="utf-8" ?>
- <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:locn="http://www.w3.org/ns/locn#"
    xmlns:ns3="http://purl.org/dc/terms/" xmlns:ns4="http://example.com/">
- <rdf:Description rdf:about="http://location.testproject.eu/so/ad/Object/AGIV/2000017467">
  <locn:address rdf:resource="http://location.testproject.eu/so/ad/Address/AGIV/2000017467" />
    </rdf:Description>
- <rdf:Description rdf:about="http://location.testproject.eu/so/ad/Address/AGIV/2000017467">
  <rdf:type rdf:resource="http://www.w3.org/ns/locn#Address" />
  <locn:geometry rdf:resource="http://location.testproject.eu/so/ad/Object/AGIV/2000017467" />
  <locn:fullAddress>Hoeilaart, Terhulpsesteenweg, 5</locn:fullAddress>
  <locn:thoroughfare>Terhulpsesteenweg</locn:thoroughfare>
  <locn:locatorDesignator>5</locn:locatorDesignator>
  <locn:adminUnitL1>België</locn:adminUnitL1>
  <locn:adminUnitL2>Vlaams Gewest</locn:adminUnitL2>
  <locn:adminUnitL3>Provincie Vlaams-Brabant</locn:adminUnitL3>
  <locn:adminUnitL4>Arrondissement Halle-Vilvoorde</locn:adminUnitL4>
  <locn:adminUnitL5>Hoeilaart</locn:adminUnitL5>
  <locn:postCode rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">1560</locn:postCode>
  <ns4:osmVisualization>http://nominatim.openstreetmap.org/search?q=Terhulpsesteenweg
      5,Hoeilaart&polygon=1</ns4:osmVisualization>
  <ns4:adminUnit rdf:resource="http://location.testproject.eu/so/au/AdministrativeUnit/STATBEL/23033"
    />
  <ns4:road rdf:resource="http://location.testproject.eu/so/tn/Road/RN/15601625" />
    </rdf:Description>
    </rdf:RDF>
```

Via the same mechanism, an HTML representation can also be returned, as shown in Figure 14.

Figure 14 – Lookup URIs via content negotiation: HTML representation

4.4 Use Case 3 – Link datasets via common address identifiers

This use case is a consequence of using *common* address identifiers to denote addresses. It is demonstrated using the Refine RDF plugin developed by Digital Enterprise Research Institue of the university of Galway [Refine].

It starts by importing the address data into Refine RDF from 'Dataset 1' mentioned in Figure 6. It contains the following fragemented address notations:

- Watermaal-Bosvoorde, Aartshertogenl., 34
- Watermaal-Bosvoorde, Aartshertogenlaan, 36
- Watermael-Boitsfort, Av. des Archiducs, 40
- Hoeilaart, Brusselsesteenweg, 87
- La Hulpe, Av. E. Solvay, 112

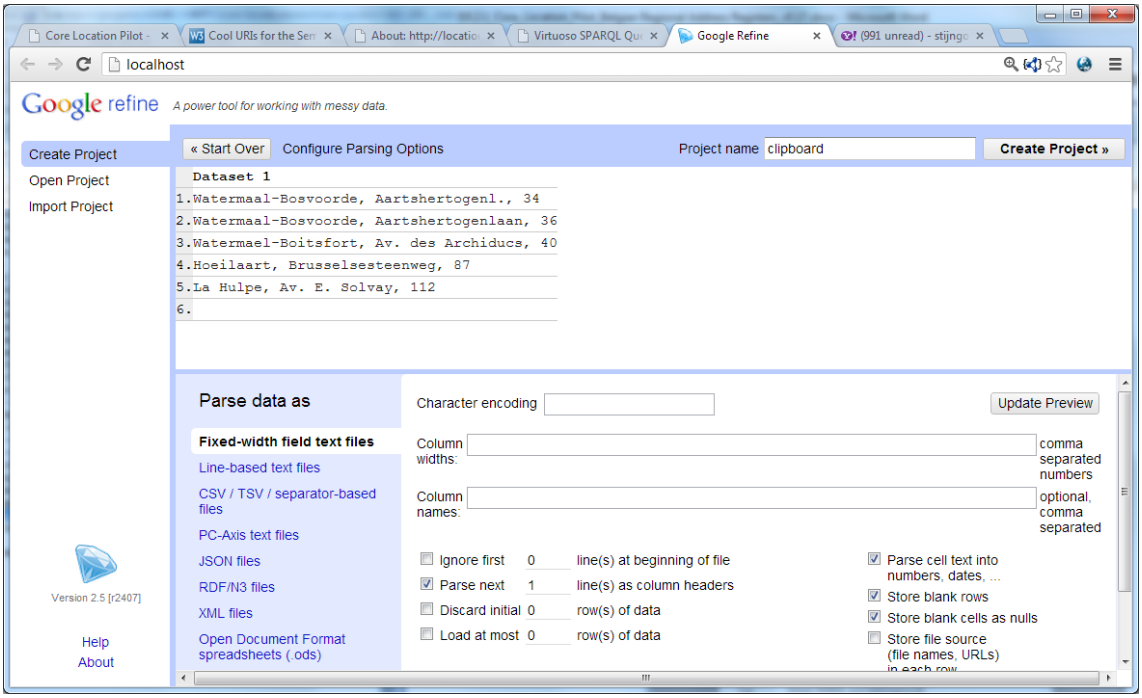


Figure 15 – Importing polluted address data in Google Refine

The next step is to configure the pilot's SPARQL endpoint as a reconciliation (disambiguation) service in RDF Refine as depicted in Figure 16. Refine RDF will try to match the address labels with locn:fullAddress strings in the linked data infrastructure. It may provide several alternatives, or allow the user to manually cleanse address data for which no matches can be found. This is depicted in Figure 17.

The end result of reconciliation (disambiguation) is that a URI value can be associated with each address label. This URI can in turn be used to retrieve additional linked data from the Web as depicted in Figure 18.

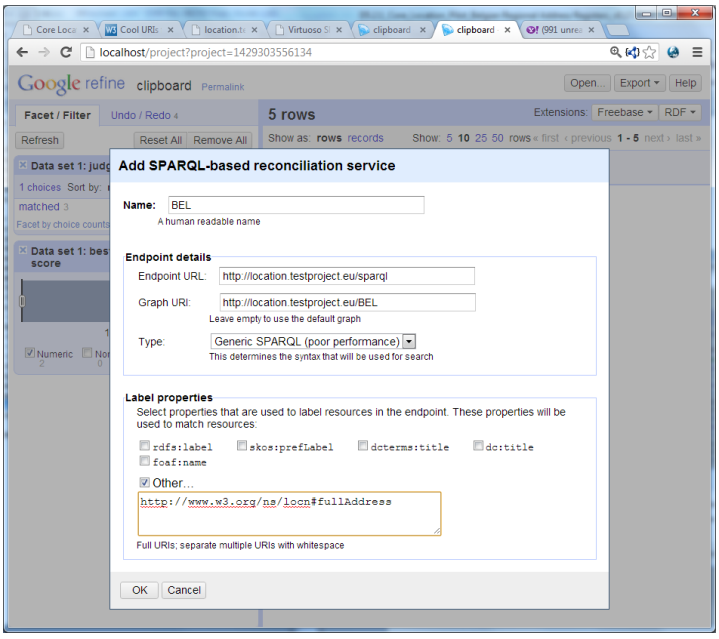


Figure 16 – Configuration the SPARQL endpoint as a 'reconciliation service'

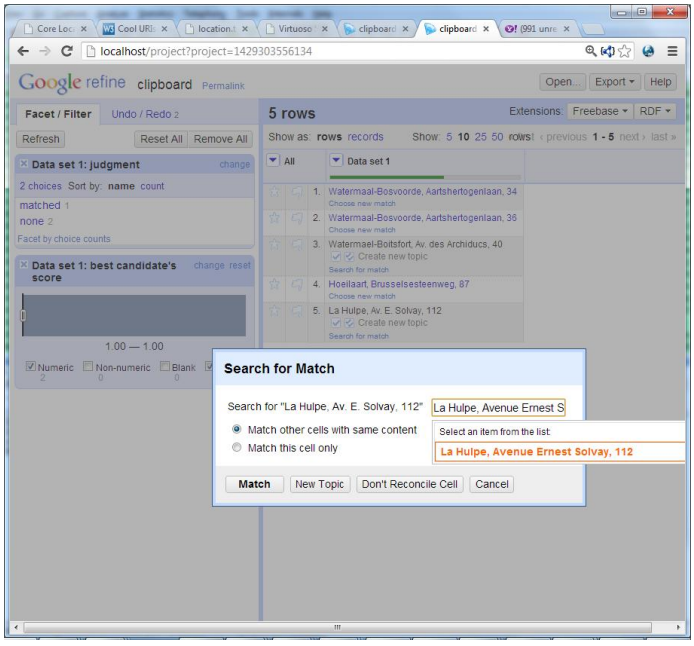


Figure 17 – Refine RDF provides semi-automated support for disambiguating address notations

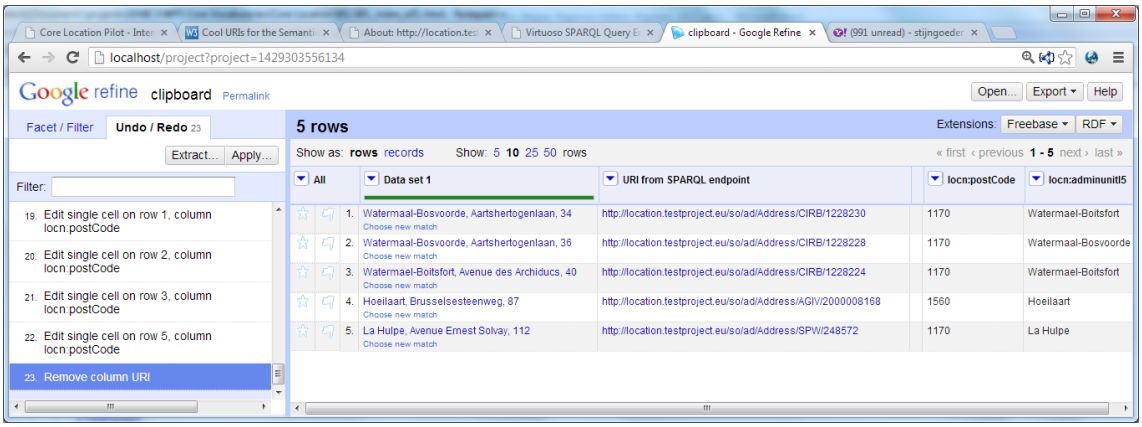


Figure 18 – Enriching address data by retrieving linked data from the Web

5 Conclusions and future work

The Core Location Pilot 'Interconnecting Belgian National and Regional Address data' has demonstrated the *technical* feasibility of the following aspects:

- The **Core Location RDF Vocabulary** can be used as a foundational RDF Vocabulary to *homogenise address data* that originates from disparate organisations and systems;
- The Core Location RDF vocabulary can be ***flexibly* extended** with experimental INSPIRE RDF vocabularies (i.e. transport networks and administrative units);
- **HTTP URI sets** can be derived from INSPIRE Unique Object Identifiers for address data, allowing to create harmonised Web identifiers for spatial things and spatial objects such as addresses ;
- A **linked data infrastructure** can provide access to *homogenised, linked*, and *enriched* location data using standard Web-based interfaces (such as HTTP and SPARQL) and Web-based languages (such as XHTML, RDF+XML), on top of either:
    - existing **relational/spatial database systems**, by applying database-to-RDF conversions**;**
    - existing **INSPIRE XML data**, by applying XSLTs to automatically generate RDF, starting from XML-encoded INSPIRE-compliant meta/data; and
- The use of standard Web interfaces (such as HTTP(S) and SPARQL) can **simplify the use of location data** for humans and machines.

Nonetheless, the pilot is only a *proof-of-concept*. In Section 3 some *technical* limitations to the provided datasets and mappings have already been reported. In addition to this, further study is required to analyse:

- **Scalability of the data infrastructure;**
- **Extendibility and configurability of the solution;**
- **Managing the entire data and metadata lifecycle.**

In addition to this, the pilot does not provide a ***business model*** that indicates why and through which funding mechanism the Belgian publication sector could develop and maintain a linked data infrastructure for location data. Such a business model should include a:

- **Cost model;**
- **Pricing model and licensing framework;**
- **Funding model; and**
- **Quantification of benefits.**

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