Why Geospatial Linked Open Data for Smart Mobility?

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1 ABSTRACT

While the concept of Smart Cities is gaining momentum around the world and government data are increasingly available and accessible on the World Wide Web, key issues remain about Open Data and data standards for smart cities. A better integration and interoperabilty of data through the World Wide Web is only possible when everyone agrees on the standards for data representation and sharing. Linked Open Data positions itself as a solution for such standardization, being a method of publishing structured data using standard Web technologies. This facilitates the interlinking between datasets, makes them readable by computers, and easily accesible on the World Wide Web. We illustrate this through the example of an evolution from a traditional Content Management System with a geoportal, to a semantic based aproach. The Traffic Safety Monitor was developed in the period of 2012-2015 to monitor the road safety and to support policy development on road safety in Flanders (the northern part of Belgium). The system is built as a Content Management System (CMS), with publicttion tools to present geospatial indicators on road safety (e.g. the number of accidents with cars and the number of positive alcohol tests) as Web maps using stardardized Open Geospatial Consortium Webservices. The Traffic Safety Monitor is currently further developed towards a Mobility Monitor. Here, the focus is on the development of a business process model for the semantic exchange and publication of spatial data using Linked Open Data principles targeting indicators of sustainable and smart mobility. In the future, the usability of cycling Infrastructure for vehicles such as mobility scooters, bicycle trailers etc. can be assessed using Linked Open Data. The data and metadata is published in Linked open data format, opening the door for their reuse by a wide range of (smart) applications.

2 SMART MOBILITY IN SMART CITIES

Cities are facing ecological and economical challenges due to the incearing influx of population. In 2010, about 75% of European Union population was located in urban areas (Caragliu et al. 2011). The concept of Smart Cities evolved as an approach to tackle the challenges (such as global warming, congested traffic, and health of an aging population) that arose due to overcrowding of the cities. Smart Cities made cities more liveable by increasing the overall quality of life through digital technologies and efficient use of the resources (Bastiaan Baccarne et al. 2014; Janssen et al. 2011; Deakin & Al Waer 2011). The use of digital technologies or technological push helps cities to plan their future by allowing cities and citizens to take into account new forms of governance, financing mechanisms and data exchange (Angelidou 2015) .The 'Smart Cities' concept quickly became a popular way to describe 'the city of the future'.

As defined by Caragliu, Del Bo, & Nijkamp (2011) in page 70 , a city is smart when " investments in capital (human and social) and traditional (transport) and modern (ICT) communication infrastructure fuel the sustainable economic growth and high quality of life achieved through wise management of available natural resources and participatory governanace". The smart city concept has six key dimensions, divided over two categories: ecological/greener (smart environment, smart economy/energy, smart mobility) and quality of life/liveable (smart people, smart governance, smart living) (Caragliu et al. 2011; Bastiaan Baccarne et al. 2014). This paper focuses only on smart mobility dimension for smart cities.

Belgium is known for traffic problems in growing cities. Besides traffic jams, road safety is a pressing question. One way to take up the challenge of lowering the number of traffic accidents and deathly victims is the evolution towards 'Smart Mobility'. It is important to ensure road safety next to a reduction of traffic congestion. In addition, the compliance with sustainable clean energy goal is also equally important when global warming is the raising concern. Smart Mobiltiy is not an isolated dimension, but part of the ecosystem of smart cities (Bastiaan Baccarne et al. 2014). The economy, use of smart technologies, citizens involvement etc is needed to understand the necessities of the citizens. Examples are the use of advanced

technologies such as smart phone applications to facilitate citizens in their commuting, empowering or involving citizens by governments to take smart decisions while commuting (promoting use of cycles, by improving cycling networks and infrastructure). Thus, to move towards smart mobility, data openness and data integration are two major aspects.

Here, 'Open Data' implies that data must be (1) available and accessible (e.g. at a reasonable price and in a handy and adjustable format; through download from the internet); (2) presented under conditions that allow the reuse and redistribution (including the merging with the other datasets); and that data availability is universal, e.g. everyone must be able to use, re-use and redistribute the data (Bauer and Kaltenböck, 2012; Khusro et al., 2014). During the past years a policy framework to provide government data as 'Open Data' was developed in Flanders. More data will be available on the web in the coming years. The web is a popular medium when it comes to the sharing of information and data. To realize the maximum benefits of the open data, there is a need of common understanding on how to process data available on the web. Data from different domains come in different formats and they must be reconciled in order to integrate. A better integration and interoperability of data through the web is only possible when everyone agrees on the standards for data representation and sharing (Fox 2013; Heather & Bizer 2011; Khusro et al. 2014). Linked Open Data (LOD) is one such method for publishing structured data using standard web technologies.

2.1 The Traffic Safety Monitor

The Traffic Safety Monitor (www.verkeersveiligheidsmonitor.be) was developed by SADL (Spatial Application Division Leuven) during 2010-2015 to monitor and support the policy development on road safety in Flanders (the northern part of Belgium) (Tirry and Steenberghen, 2013a). The aim was to support the accessibility, the quality and the interoperability of indicators for road safety. Examples of spatial indicators on road safety are: the number of accidents with cars, number of deaths due to accidents, the number of positive alcohol tests etc.

The Traffic Safety Monitor (Figure 1) was deployed as geospatial Content Management System (CMS) based on Drupal. The viewing (WMS[1]) and downloading capabilities (WFS[2]) using standard Open Geo Consortium (OGC) web services were implemented with the integration of Open Layers, Geoserver and PostGIS. Because of privacy concerns, WFS service was available only to registered users at the time. The focus was also on providing an extensive metadata with the target that anyone should be able to recalculate the indicators themselves. A standard metadata template stores the non-spatial information such as creator, temporal information (date of publishing/updating), reference, data quality along with spatial metadata like Spatial coverage (Flanders), Spatial representation (vector/grid), Spatial Reference System (ESPG code). Both geospatial indicators as maps and metadata are made available to the users of the Traffic Safety Monitor

From 2016 onwards, the Traffic Safety Monitor is being further developd as the Mobility Monitor. Here, the aim is to bring together data from five core themes related to mobility that are important at the regional and local level:[3] accessibility, road safety, reachability, liveability and environment. Some indicators are: particulate matter maps, dagebrous points in the roads abd accidents with cyclist. The maps will be converted into GeoLinked data and made available for download both via WFS and as RDF.
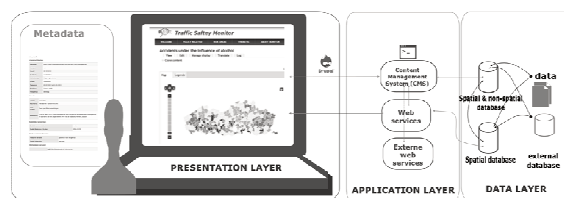

Figure 1: Logical Model of Traffic Safety Monitor Flanders

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[1] A Web Map Service (WMS) is a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database.

[2] Web Feature Service (WFS) provides an interface allowing requests for geographical features across the web using platform-independent calls.

[3] http://ec.europa.eu/transport/themes/urban/doc/ump/com(2013)913-annex_en.pdf>
http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2015-0246+0+DOC+XML+V0//EN

2.2 Research objectives

The conversion of the data into LOD format involves a series of standards and technologies. Several authors proposed life-cycles or tehnologies for Linked Data conversion (Auer et al. 2012; Zaveri et al. 2012; Lopez-Pellicer et al. 2011; Heather & Bizer 2011). However, a need for simplified but detailed operational steps of the LOD conversion process was felt while applying the principles of LOD in the frame of the Traffic Safety Monitor. Thus, the focus lied at the development of a business process model for the semantic exchange of spatial data. The main objective is to incearse the interoperability[4] among data from different domains/sources.

After a brief outline of the use case 'Cycling infrastructure in Flanders as Geospatial LOD', the concepts and methods used for the adaptation to the new technology of Geospatial LOD is given. The paper focuses on the standardised roadmap for the creation of geospatial Linked Open Data presented in the 'Results' section. The key finding and challenges encountered are discussed further. Finallly, we draw conclusions about the role of the LOD in the scope of smart mobility.

3   USE CASE: CYCLING INFRASTRUCTURE IN FLANDERS AS GEOSPATIAL LOD

The transformation of mobility in a smart direction requires an alternative sustainable means of transport to private vehicle such as cycling (Garau et al. 2016). The evaluation of the urban mobility can be done with indicators of mobility (Garau et al. 2015). The 2013 annual report on Road Safety in Flanders by Carpentier et al. (2014) indicates that cyclists make up 20% of the total number of traffic victims. Also, cyclists are the largest group of deathly victims within the built-up area (29%). In their report, the authors demand attention for the improvement of infrastructure, such as the separation of cycling tracks from the road and cycle highways (Carpentier et al., 2014). Figures from the European Transport Safety Council (ETSC) indicate 9.5 cycling deaths per million inhabitants, a figure far above the European average of 4.2 cycling deaths (Adminaite et al., 2015).

To provide a basis for the Traffic Safety Monitor, Tirry and Steenberghen (2013a) developed a general policy-oriented conceptual framework for monitoring. This conceptual framework was specified for the use case "cycling infrastructure as Geospatial LOD (Figure 2). To better map the impact of the type and condition of cycling infrastructure on accidents, there is a need for qualitative and semantic interoperable data. Therefore, we focused on the publication of "cycling infrastructure data" as Linked Data, starting with a semantic exchange model of the metadata for the accidents and cycling comfort data (Tirry and Steenberghen, 2013b). The case study is the publication of the "cycling infrastructure map" as Geospatial Linked Opend Data. The usability of the cycling infrastructure to the mobility scooters, bicycle trailers and links to the other external vehicular characteristics such as loading poles can be accessed in the future.
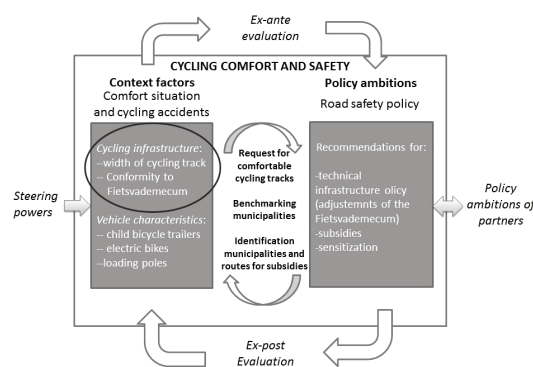

Figure 2: A conceptual framework for monitoring applied to cycling comfort. This study focuses on the publication of "cycling infrastructure data" as Linked Data. Based on the generic monitoring framework by Tirry and Steenberghen (2013a).

3.1 Data

We used the "cycling infrastructure data" that represents the Supra-local Functional Cycling Route network (Bovenlokaal Functioneel Fietsroutenetwerk - BFF). This network is under development by the Flemish Policy to ensure a safe journey by bike for house, school and work movements. To develop and realize the

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[4] "capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units" (OpenGIS, 1996).

BFF, the Flemish Government structurally collaborates with the provinces. The Agreement 'Support of the Supra-local cycling policy' ('Ondersteuning van het bovenlokaal fietsbeleid') between the Flemish Government and the provinces states that the provinces are responsible for the design and management of the BFF. Provinces are also responsible for the inventory of cycling infrastructure along non-regional roads that are part of the BFF. A complete inventory of the BFF is required to control the conformity[5] of the BFF. These inventory data are stored in a geographical information system (cyclingGIS – fietsGIS) which is coordinated by the Flemish Government, Department of Mobility and Public Construction Works and currently under development by the company Geosolutions. The cycling infrastructure data is received in 'shapefile' format which is uploaded to a PostGIS database.

3.2 Methods

3.2.1 BPMN

BPMN is a standard for process modelling, defined by the Object Management Group (OMG). The graphical notation that is created to provide a unified language of worldwide acceptance for the specification of business processes (Silver, 2009). The use of Business Process Modeling Notation (BPMN) process allows the stadardisation of the workflow, with an ability of automatization/semi-automisation of the process. The process modeling allows to analyze, design and diagram a business process flow. We used the Bizagi Modeler[6], an open software that enables to visually diagram, model and document business processes in industry-standard BPMN.

3.2.2 Ontologies

The term "Ontology" origins from the domain of philosophy and refers to the philosophical investigation of an existence. In the context of Semantic Web, the most commonly used definition comes from Studer et al. (1998): "An ontology is a formal explicit specification of a shared conceptualization of a domain of interest". The different elements of this definition are defined as follows (Studer et al., 2007):

- Formal: Data is machine-processable and can be interpreted in a well-defined way.

- Explicit: all concepts must be explicitly defined to make them machine-interpretable. Some concepts make sense for humans, but not for machines.

- Shared: There is a consensus about the conceptualization.

- Domain specification: The focus lies on knowledge about a particular domain.

Thus, ontologies facilitate communication between people on one hand and heterogeneous and widely spread application systems on the other by providing shared common understanding of a domain (Pinto & Martins 2004; Verborgh 2014))

Vocabulary: Vocabulary is the set of terms (classes and property names) that could be used in a domain. Ontology specifies how these vocabulary terms can be used. An ontology defines what is the class (TopographicObject), what is the subclass (road), and the properties these class/subclass can have, like "has address", "has-location" etc. (Hart and Dolbear, 2013). Taxonomy: A controlled vocabulary that has been structured into a hierarchy. A taxonomy is often "is a kind of" relationship (Hart & Dolbear 2013; Noy & McGuinness 2001).

Protégé 5.0 (developed by Standford Center for Biomedical Informatics Research), a free and open source software is used for creating the ontologies in our case. It provides a platform to construct domain models and knowledge based application ontologies. For an in-depth guide to building ontology in Protégé, we refer to Horridge (2011).

3.2.3 Linked Open Data

In the recent years, LOD is seen as an emerging technology that helps both humans and computers with an unambiguous understanding of data and their processing. LOD guides to achieve the vision of the Semantic

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[5] For guidelines concerning conformity of the cycling infrastructure, we refer to Vademecum Fietsvoorzieningen, available at: http://www.mobielvlaanderen.be/vademecums/vademecumfiets01.php

[6] http://www.bizagi.com/

Web. The Semantic Web, first mentioned by Tim Berners-Lee (2000), allows data to be shared and reused across different platforms thanks to the use of standards and a set of principles. The term 'Semantics' mean that there is an agreement on the meaning of an object or entity. For example, if we talk about an entity or object named 'road', it should have an explicit definition that everyone understands in the same way, no matter where you live or from which culture you are. The Semantic Web is a vision on technology in which computers are capable of understanding the exact meaning of data. This makes machines intelligent so they can process and link the datasets and LOD is a method to attain this vision of Semantic Web. LOD data builds upon the standard web technologies, like Hypertext Transfer Protocol (HTTP) and Uniform Resource Identifier (URI).

Berners-Lee (2000) four design principles of Linked Open Data are :i) Use Uniform Resource Identifiers (URIs) to name the data entities; ii) Use Hypertext Transfer Protocol (HTTP) URIs , so the information can be looked up in the web and description of the particular entities can be retrieved ("dereferenced"); iii) Provide a useful information using open standards like the Resource Description Framework (RDF), SPARQL Protocol and RDF Query Language (SPARQL to encode the information and query them. iii) Provide links to related URIs (other information), so people can discover more. The use of these design principles ensures that data of different sources can be connected and queried (Bizer et al., 2009). These principles are summarized in a "5 star" deployment scheme[7] (Figure 3). This 5 Star Linked Data system is cumulative, meaning that each additional star presumes that the data meets the criteria of the previous step(s).

☆ Data is available on the Web, in whatever format.
☆☆ Data is available as machine-readable structured data, (i.e., not a scanned image).
☆☆☆ Data is available in a non-proprietary format, (i.e, CSV, not Microsoft Excel).
☆☆☆☆ Data is published using open standards from the W3C (RDF and SPARQL).
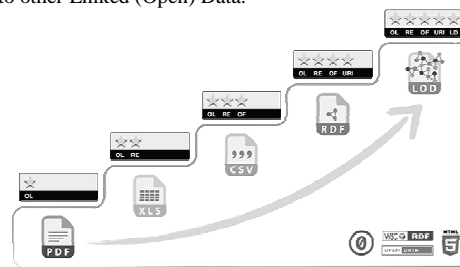☆☆☆☆☆ Data is all of the above and links to other Linked (Open) Data.

Figure 3 The "5 stars" deployment scheme of Linked Data by Berners-Lee. Source: http://5stardata.info/en/

3.2.3.1 Geospatial Linked Open Data

Geospatial data is recently becoming available as LOD (Koubarakis & Kyzirakos 2012; Batte & Kolas 2012). It differs from other data since the representation of real world entities and their topological relationship should be defined explicitly. There is need for understanding of some general concept of Geographic Information System (GIS), so is discussed breifly further. Any entity in the real world such as traffic lights, road, city is called a 'feature', and each feature has a location x (latitude) and y (longitude). These features are represnted using mainly three types of geometries: traffic lights can be represented a point geometry, roads can be represented as a line geometry and city as a polygon geometry There is always some kind of a spatial realtionship among the features of the real world. The roads can intersect with the boundary of the city, the road contains traffic lights. The topological relationships (equals, disjoint, touches, inside, covered by, contains etc) has been defined by Simle Features Geometry, Egenhofer and RCC8 (Batte & Kolas 2012; Patroumpas 2014). Consequently, in LOD, RDF vocabularies and SPARQL queries meant for non spatial data are not capable to handle the spatial data. GeoSPARQL[8] is an extension to SPARQL for dealing with geospatial data. As we are dealing with the spatial data, we use GEOSPARQL for both representation and querying.

GeoSPARQL states a standard way to express topological relationships, i.e. spatial properties between topographic features, and to query them. The OGC Simple Feature model represents a spatial object as an

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[7] http://5stardata.info/en/
[8] http://www.opengeospatial.org/standards/geosparql

OGC feature (Figure 4). There are three key classes for such representation in the GeoSPARQL ontology (Batte and Kolas, 2012; Perry and Herring, 2012):

Feature: an entity in real world with some spatial location; i.e. a municipality;

Geometry: A representation of a spatial location; i.e. a set of coordinates; Any geometric shape: point, line or polygon

Datatype for geometry: Geometry can be represented using Well-Known Text (WKT) or Geographic Markup Language (GML). WKT is the most commonly used, as defined by the Simple Feature Model International Organization for Standardization (ISO) 19125-1. The WKT format (or serialization[9]) for points, lines and polygons looks as follows:

Point: Point (x, y)

Line: Linestring(x1,y1 , x2 y2 …….xn,yn)

Polygon: ((x1,y1 , x2 y2 …….xn,yn), (a1,b1 , a2 b2 …….an, bn)

Spatial object: A superclass of both Features and Geometries. The class geo:Geometry is a top class which is a superclass of all geometry classes.
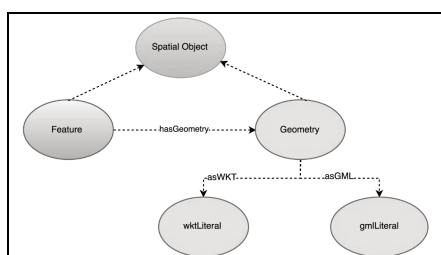

Figure 4:GeoSPARQL ontology. Source: Koubarakis and Kyzirakos (2012)

In addition to ontologies, GeoSPARQL also has reasoning capabilities. This includes a standard way to express topological relationships (spatial properties between topographic features) and to query them. This makes it possible for example to check whether two roads intersects or not. GeoSPARQL provides a set of standard functions for spatial calculations such as. geof:sfDistance (to find distance between two geometric points), geof:sfBuffer (to find for example bus stops located within 200m) (Perry & Herring 2013; Perry & Herring 2012; Batte & Kolas 2012). Thus, providing a platform to do simple spatial queries. However, is still in development to include the functionalities as in GIS tools.

3.2.4 Conversion Tool Selection

There are several tools available for the conversion to LOD depending on the format of data (csv, Realtional Database, shapefile etc.). This study focused on automatic conversion using a tool that has geospatial capabilities as manual conversion is cumbersome or almost not possible when there are more than 1000 rows. The conversion of the raw data in RDB to RDF can be done with several software tools, namely: Geometry2RDF, SPARQLify, TripleGeo and GeoTriples. Here, we list and compare only those softwares with spatial capabilities (Table 1).

Tools	Direct Maping [10]	R2RML[11]	RML[12]	Automatic Mapping Generation	GeoSPARQL Compliance	RDMS	ESRI Shape file
Sparqlify[13]	-	-	-	-	-	√	-
Geometry2RD[14]F	√	-	-	√	√	√	√

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[9] The proces of transformation of RDF into data format for publication on the web
[10] Direct mapping from relational data to RDF (http://www.w3.org/TR/rdb-direct-mapping/)
[11] A language for expressing customized mappings from relational database to RDF datasets (http://www.w3.org/TR/r2rml/)
[12] An extension of R2RML (http://semweb.mmlab.be/rml/spec.html)
[13] http://sparqlify.org/wiki/Sparqlification_mapping_language
[14] Geometry2RDF is the plugin within Geokettle (a powerful and metadata-driven Spatial Extract Transformation Load tool

TriplesGeo[15]	√	-	-	-	(√)	√	√
GeoTriples[16]	-	√	√	√	√	√	√

Table 1: Comparison of different conversion tools (Kyzirakos, 2015)

After a comparison of the available tools, GeoTriples was chosen as it has the most extensive capabilities supporting geospatial data which makes use of R2RML mapping. GeoTriples is a semi-automated tool that allows the publication of geospatial information as RDF using GeoSPARQL vocabularies. It is not tightly coupled however to a specific vocabulary, so user-defined vocabularies can be used as well (Kyzirakos et al., 2014). The mapping generator can use tailored scripts called mapping for conversion into the RDF data model.GeoTriples supports four types of data sources for direct mapping: Database (Relational Database such as PostGIS); Shapefile (ESRI shapefile); RML (R2RML mapping file) and also KML[17] (Keyhole Markup Language). Then, GeoTriples uses these mappings to generate the RDF output, also called RDF graph or RDF triple, in different standard formats such as N-Triple (default), Turtle and RDF/XML.

4 RESULTS

We provide a standardized workflow created in BPMN for publishing of the cycling infrastructure data as Geospatial Linked Open Data (Figure 5). The simplified and comprehensive method behind this workflow is mainly based on best practices from the W3C Linked Data Cookbook[18], the LINKVIT project[19], and the work by Hart and Dolbear (2013). The process of Linked Data publication is divided in four phases (Figure 5) and are discussed below.
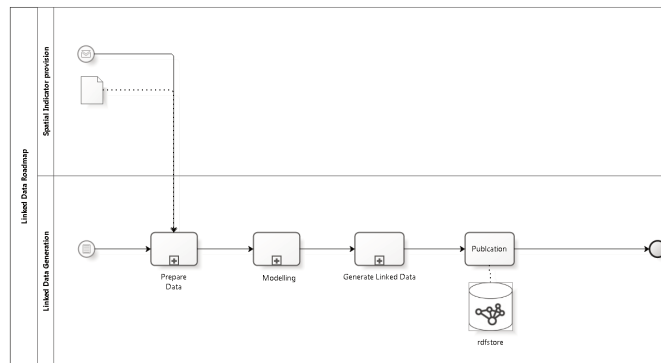

Figure 5: Business process model in for the publication of cycling infrastructure as Linked Open Data. The model is developed using Business Process Modeling Notation (BPMN)

4.1 Phase 1: Prepare data

Figure 6:BPMN scheme of Phase 1 'prepare data' of the standardized workflow for publishing Linked Data

The first phase of data preparation is given in Figure 6. The initial tasks are to define the purpose of data (What is the current/future use?), to set the scope (What is important?) and to formulate competency questions (What queries can be done ?).

Here, the main reason for publication of the cycling infrastructure as the Geospatil Linked Open Data is to stimulate open innovation by providing the data and opportunity to link these data to other datasets. For example, events could be published along the cycling road such as charging stations for electric bikes; and the compatibility could be checked between infrastructure and vehicles using it; which parts of the BFF are already suitable for child bicycle trailers.

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[15] https://github.com/GeoKnow/TripleGeo

[16] https://github.com/LinkedEOData/GeoTriples

[17] An OGC standard file format used to display geographic data in mapping applications like google maps. http://www.opengeospatial.org/standards/kml/

[18] http://www.w3.org/2011/gld/wiki/Linked_Data_Cookbook

[19] http://www.linkvit.eu/en/

Defining the scope helps to decide what should and shouldn't be included for the conversion; The scope of the case here, is to provide open access to the characteristics and suitability of the cycling infrastructure. Any idea about the kind of questions that should be answered correctly by the RDFS ontology and accompanying data also helps to select the suitable and necessary data. It is advised to have as many competency questions as necessary to cover all queries that are expected to be asked by the users of the Linked Data. Some examples in our case are: Which bicycle lanes are conform with Vademecum guidelines? , What is the breadth of the cycling track at a certain location?, What is the nearest cycle track from a work location ? The scope helps to determine what fields are needed. The cycling infrastructure dataset has an extensive inventory with 42 attributes defining cycling infrastructure characteristics, type, built-up material, etc. The selection of 15 attributes are made in the beginning that are interesting, useful and can answer the competency questions formulated above.

The next steps to be taken are: to clean the data by removing inconsistencies and duplicates, elaborate on the field names (field names that are ambiguous and perhaps shortened due to limitations on string length of used database technology). There are different tools available for performing the above mentioned tasks. These tools range from a general purpose spreadsheet (like MS Excel) [20] to dedicated data cleansing tools (like Open Refine[21]). After cleaning for the inconsistencies, at the end of the Phase 1 process we can upload the shapefile into a PostGIS table.

4.2 Phase 2: Modelling

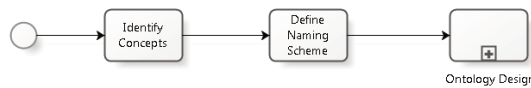This modelling phase is often the most complex and crucial part of the Linked Data design (Figure 7).

Figure 7: BPMN scheme of Phase 2 'modeling' of the standardized workflow for publishing Linked Data

4.2.1 Identify concepts

The database is documented for the development of a conceptual model of the data by defining concepts and their relationships and properties. The process normally starts with a rough sketch to express how the concepts are related to each other and to real world things. For example: we can relate the cycling infrastructure and its attribute length by forming simple sentence: "Cycling Infrastructure has a length" and "Length is measured in cm". After the documentation of the attributes (Table 2) and rough analysis, the following concepts were identified and summarized in a detailed scheme.

- Cycling infrastructure: A geographical area that is part of a road network. It is defined by the line geometry specially meant for bicycles.

- Inventory: All the measurements related to cycling infrastructure such as length, breadth, type and breadth of the separation strip between cycle track and adjacent road.

- Characteristics: The characteristics of the cycle track including material, cycling direction, morphology etc., given in certain units of measurement.

- Quality Assessment: The conformity test that measures the compliancy with the Vademecum Fietsvoorzieningen .

Field Name	Field Full Name	Type	Unit	Example	Comments for RDFS Ontology
Ws_oidn	Roadregister_ObjectIdentification_ number	number		603099	Official ID from the road register
Materiaal	Material	string		asphalt	Building material of the Cycling Infrastructure
Breedte	Breadth	number	cm	100	Breadth of cycling infrastructure. Value = min:0 – max 500cm

Table 2 Example of documentation of database for identifying concepts

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[20] http://schoolofdata.org/handbook/recipes/cleaning-data-with-spreadsheets/
[21] https://github.com/OpenRefine/OpenRefine/wiki/Getting-Started

4.2.2   Define Naming Scheme

The first principle of Linked (Open) Data tells us to "Use Uniform Resource Identifiers (URIs) to name (identify) things" (Berners-Lee, 2000). A scheme is defined for assigning persistent URIs to the dataset. The European Interoperability Solutions for European Public Administrations (ISA) initiative[22] has published ten rules [23] for using persistent URIs [24]. Following these guidelines, the following structure is used:

{domain}{type}/{dataset|ontology}/{concept}/{reference} where

{ domain }	An internet domain (URL) controlled by data owner where the data will be published and the URIs can be dereferenced. Here, the domain is 'verkeersveiligheids.be'
{type}	Type is 'id' of the URI is an identifier of an object (individual/instance); 'resource' if it refers to the metadata about an object; 'vocab' if it refers to the definition of a concept in an ontology.
{dataset|ontology}	This is either the short name of the dataset, or the short name of the ontology.In our case, we use the name 'CyclingInfrastructure' for the dataset, and 'CyclingInfrastructureOntology' for the ontology.
{concept}	This is the name of the concept referred to by the object that is identified by the URI.
{reference}	A unique number or code that identifies the object within the namespace. This reference can be both a name or a number, as long as it is unique and not too long. Concepts in an ontology are referenced by their name. Therefore, the {reference} is left empty. Instead a slash (/), the hashtag (#) is used to separate the {concept} from the rest of the URI. Both '/' and '#' has its own advantage and limitations. In our case, '#' is used as it best fits our data.

The resulting persistant URIs are:

For ontology:

< http://www.verkeersveiligheidsmonitor.be/vocab/2015/CyclingInfrastructureOntology.owl# >

For data corresponding to the cycling infrastructure:

< http://www.verkeersveiligheidsmonitor.be/data/CyclingInfrastructure# >
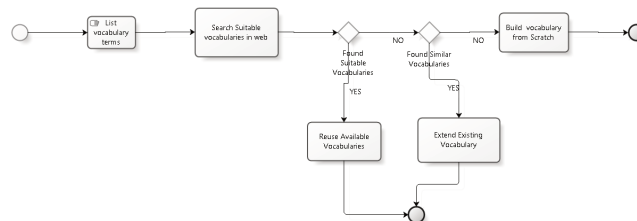
4.2.3   Ontology Design

Figure 8 BPMN scheme of the subprocess 'Ontology design', part of the standardized workflow for publishing Linked Data

After the identification of concepts, properties and relations, then defining the naming scheme, we move up to the ontology design. Ontology design is in fact a subprocess with own start and end events (Figure 8). One of the first recommended steps towards building an ontology is to determine the domain and scope of the ontology to be developed, and to write down a list of terms to be represented in the ontology, called vocabulary (Noy and McGuinness, 2001; Studer et al., 1998). Terms of this vocabulary represent specific types of things. The definitions of the terms provided by the vocabularies using formal language/standards (RDFS or OWL), bring clear semantics (meaningful data) to descriptions and links (Alani, 2006).

After listing the terms, an ontology design process continuous with the search for reusable existing vocabularies. LOV was used as a search engine to sarch for existing vocabularies. There are several web repositories for searching such existing ontologies, like Linked Open Vocabularies (LOV), Swoogle and Watson etc. The LOV repository has a comprehensive view of available RDF schemas and vocabularies. Its interface makes it easy to search and provides additional information, like metadata of vocabularies, classification by vocabulary spaces and interlinks to other vocabularies (Community, 2013).

It is possible that the matching vocabularies do not exist in these repositories. Then, suitable vocabularies could be built by extending existing vocabularies, or new vocabulary could be built from scratch (Noy and McGuinness, 2001) depending on the situation. The decision making process whether to build ontologies

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[22] http://ec.europa.eu/isa/index_en.htm

[23] https://joinup.ec.europa.eu/community/semic/document/10-rules-persistent-uris

[24] https://joinup.ec.europa.eu/sites/default/files/c0/7d/10/D7.1.3%20-%20Study%20on%20persistent%20URIs.pdf

yourself is modelled in BPMN (Figure 8) and is based on literature (Corcho et al., 2003; Noy and McGuinness, 2001; Studer et al., 2007).

Though LOD principles recommends you to reuse ontologies when possible. After the extensive search, the decision was to create own basic ontology for the dataset in addition to using some existing ontologies and vocabularies (Table 3) . There was indeed a requirement to develop ontologies for the terms that did not exist yet in the repositories. The advantage of developing your own ontology is that the meaning is closely matched to your data structure. Also, you do not require knowledge of other external ontologies and publication time is faster. The only disadvantage might be that the data becomes less accessible as data users/consumers are less familiar with the ontologies developed by you.

Classes	CyclleLaneCharacteristics, CycleLaneInventory, QualityAssessment etc
Properties	hasQualityAssessment, hasCyclingDirection, hasServiceType etc
Imported properties	rdf[25]:comment, rdf:label, ogc:hasGeometry, ogc[26]:Geometry, ogc_asWKT etc

Table 3: Some of the classes and properties for cycling infrastructure ontologies

The ontology describing the cycling infrastructure inventory and characteristics of the selected attributes are shown in Figure 9. The format used for saving the ontology files is RDF/XML.
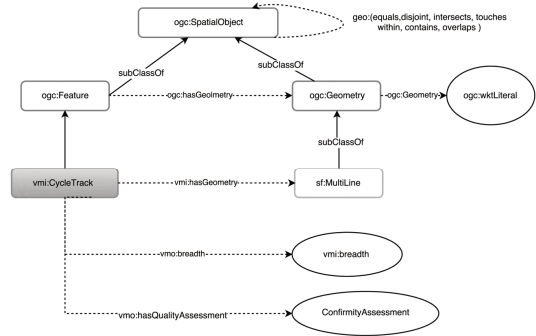

Figure 9:Ontology model for the cycling infrastructure Data

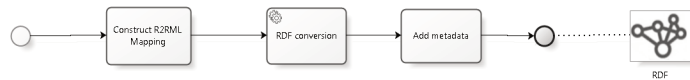## 4.3 Phase 3: Linked Data Generation/RDF creation

Figure 10: BPMN scheme of Phase 4, modeling, of the standardized workflow for publishing Linked Data

The next phase consists of the generation of Linked Data from a Relational Database (Figure 10). The conversion of a Relational Database (RDB) , or term 'mapping' in our case, is defined in a simplistic way:

- A subject corresponds to a column in the table with an unique id (primary key) concatenated with the namespace URI of a resource.
- Each column name of an RDB table is a RDF predicate.
- Each RDB table cell value is an object.

4.3.1 R2RML Mapping

The RDB to RDF Mapping Language (R2RML) is a W3C standard for creating customized mapping from relational data to RDF following both structure and target vocabulary given by user (Kyzirakos et al., 2014; Sequeda et al., 2012). The R2RML mapping makes the data retrieved from an input database explicit and better comprehensible than information coded in another proprietary language, in addition to making it easier to reuse for other tables (Hart and Dolbear, 2013).

TriplesMap: A mapping rule for R2RML is referred as TriplesMap (Figure 11). It has three components: i) Logical Source, ii) Subject Map, and iii) one or more Predicate-Object Maps.

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[25] 'Rdf' is a prefix used for the namespace of RDF standard
[26] 'ogc' is a prefix for the namespace of GeoSPARQL standard

Logical Source

A Logical Source refers to a table of the PostGIS database we want to map(rr:logicalTable). It can be that can a SQL view[27] or a valid SQL select query that you are going to convert to RDF. Example:

rr:logicalTable [rr:tableName "cyclingInfr"]

Note: 'rr' is a prefix for the namespace of r2rml standard 'http://www.w3.org/ns/r2rml#' / 'cyclingInfr' is the name of the SQL view table in the PostGIS database

Subject Map

Subject Maps generates a URI from the combination of a column in a logical table (mostly Primary Key relation) with a namespace (Section 4.2.2). A subject map consists of an URI pattern (rr:template) that defines a subject or URI template for each row; a class (rr:class) corresponding to the ontology class for that table. Example: We want to give unique identifier for each geometry and also defin the class Geometry using GeoSPARQL vocabulary.

rr:subjectMap   [rr:class   ogc:Geometry;   rr:template 'www.verkeersveiligheidsmonitor.be/resource/cyclinginfrastructure/Geometry/{"gid"}';];

Predicate Object Map

In Predicate-Objet Map (rr:predicateObjectMap), the attributes of tables (columns) are mapped using suitable ontology properties using Predicate Object Maps. A TripleMap can have one or more rr:predicateObjectMap. This map is further divided into two division:

A Predicate Map specifies the property relationship between a subject and an object.

An Object Map specifies the object column and datatype properties for a value corresponding to that column.

Example: The column "asWKT" which contain the information of the latitude and longitude of the cycling infrastructure is defined using predicate 'asWKT' and datatype 'wktLiteral' of GeoSPARQL vocabulary.

rr:predicateObjectMap [rr:predicate ogc:asWKT;

rr:objectMap [rr:datatype ogc:wktLiteral;rr:column '"asWKT"';];];
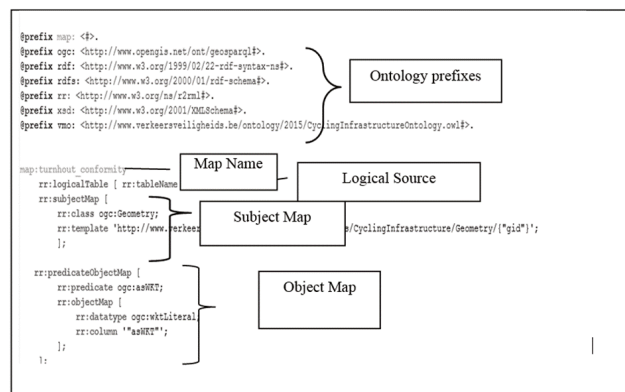

Figure 11: R2RML Mapping: Example of a triplesmap

4.3.2   RDF conversion

After the completion of the R2RML mapping process, the next step is to use GeoTriples for generating RDF output. As discussed earlier in Section 3.2.4, GeoTriples was chosen as it has the most extensive capabilities supporting geospatial data which makes use of R2RML mapping. We decided to work with semi-scripted conversion techniques, i.e., using own script. Command Line was used rather than GUI as the errors in script could me accessed and was convenient while running the script multiple times. The '.rml' file created during the previous process (Construct R2RML Mapping) for the automatic to RDF triples. The file is saves as N-triples with '.nt' extenstion.

---

[27] Postgis view table created from SQL query with only selected attributes

4.3.3   Add metadata

The addition of metadata (Semantic Metadata in this case) is crucial for the assessment of data quality (Vrandecic and García-castro, 2013). Metadata provides information about the data itself such as origin, data production; temporal dimension (until when is data valid for use), provenance[28] and for which theme/applications the data can be used. Introducing data with such self-description allows users to make decisions about whether to re-use data while considering reliability and usability.

In April 2015, GeoDCAT-AP [29] an extension of DCAT-AP for geospatial datasets, data series and services has been initiaated by Joint Research Centre(JRC) of the European Commission (EC) (Patroumpas et al. 2015). The metadata specifications will also contains the vocabularies for transport networks (Veeckman et al. 2016). At the time of reseach such development has not been made. Thus, the basic metadata (description, publisher, modification date, creation date, creator and vocabulary used for the dataset) is documented using Dublin core (http://purl.org/dc/terms/) and Data Catalog Vocabulary (http://www.w3.org/ns/dcat#) (See below). However, in future GeoDCAT-AP will be used for documenting metadata.

@prefix dcterms: <http://purl.org/dc/terms/>.

@prefix dcat: <http://www.w3.org/ns/dcat#> .

#---------Data Set METADATA--

vmi:dataset-001 a dcat:Dataset;

dcterms:title "Cycling Infrastructure of Turnhout "@en ;

dcat:keyword "Cycling Infrastructure", "Quality Assessment", "Measurements" ;

dcterms:description "Cycling Infrastructure Dataset for Turnhout, type BFF"@en ;

dcterms:created "2015-11-06"^^xsd:date ;

dcterms:modified "2015-11-06"^^xsd:date ;

dcterms:identifier <http://www.verkeersveiligheidsmonitor.be/cms/indicator/CyclingInfrastructure> ;

dcterms:publisher "Policy Support Center Flemish Government for Traffic Safety Monitoring";

dcterms:language <http://id.loc.gov/vocabulary/iso639-1/en> .

4.4 Phase 4: Linked Data Publication

In this phase, the dataset is uploaded to the triplestore. There are different stores available for publishing the dataset, both as research prototypes and commercial stores . Based on the inventory of available publication tools for supporting Geospatial Semantics, we can state that the choices for suitable publication tool in the frame of the Traffic Safety Monitor are limited. Because most triplestores only support the publication of two dimensional point data and do not support GeoSPARQL ontologies and function. The geometry of cycling infrastructure is represented as Multilines (combination of several lines). Thus, limiting the choice of available tools. Only Parliament[30] and Strabon[31] appear to provide the most extensive functionalities concerning geospatial data (Bereta et al., 2013, Kyzirakos et al., 2012. Yet, Strabon is not compatible with GeoSPARQL and currently not under active development). As Parliament supports (i) the functionalities of GeoSPARQL and (ii) all geometry types (point, line, polyline, polygon), and because it is an open source software, we use Parliament as a triplestore for publishing and querying Linked Data in the semantics exchange model of the Traffic Safety Monitor (Koubarakis et al., 2012, Batte and Kolas, 2012; Kolas et al., 2009). We refer to Batte and Kolas (2012) for an overview of the topological functionalities supported by Parliament. The strengths and weaknesses of Parliament are summarized in (Table 4).

Parliament	
Strengths	*Weaknesses*
Implementation of GeoSPARQL standard	Research prototype

---

[28] Provence refers to the process of development of data

[29] https://joinup.ec.europa.eu/asset/dcat_application_profile/asset_release/geodcat-ap-v10

[30] http://parliament.semwebcentral.org/

[31] http://www.strabon.di.uoa.gr/

Creation of Spatial index	Still not fully stable
Actively under development	

Table 4: Strengths and weaknesses of Parliament

The .ttl (turtle) and .nt (N-Triples) files generated in the previous sections are uploaded in this store. Parliament is only installed in localhost. As discussed earlier, the software is still in a development phase and is still too unstable to go into production. Then, the files can be uploaded into a default RDF graph. Parliament works with creating indexes of two types, Temporal and Spatial, which enables it to have faster query performance and better space usage (Batte and Kolas, 2012; Kolas et al., 2009). Therefore, it is important to check whether the index has been created or not.Now, Parliament is ready for query. The output of the query can be made available in several RDF data formats (RDF/XML, .rdf, GeoJSON[32]) so that data users have a choice and can select the method that best suits their purposes.

4.4.1   GeoSPARQL queries

After generating the Linked Data, the next step was to run the spatial queries to see the performance of the Parliament triple stores. As the queries on Linked open data are complex, we provide first an example of simple query then GeoSPARQL query.

Query 1: Find the cycling infrastructure with breadth more than 150 and conform with the Conformity test of the Vademecum Fietsvoorzieningen.[33]

```
1.  PREFIX ogc: <http://www.opengis.net/ont/geosparql#>
2.  PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
3.  PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

4.  PREFIX vmo: <http://www.verkeersveiligheidsmonitor.be/vocab/2015/CyclingInfrastructureOntology.owl#>

5.  SELECT  ?breadth ?conformity ?geom

6.  WHERE {

7.  ?s  vmo:hasQualityAssessment ?conformity;
8.      vmo:breadth ?breadth;
9.  ogc:hasGeometry/ogc:asWKT ?geom.

10. FILTER (?breadth >=150 &&  lcase(str(?conformity))="fietsinfrastructuur conform")

11. }
```

Lines 1 - 4 provide the prefixes for the namespaces of ontologies used to describe the data.
Line 5 specifies the selection of variables we want to return as result. In this case these are the variables breadth of cycling infrastructure, result of conformity test and the geometry (multiline segments).
Lines 6 - 9 specify the relationships for selecting the triples. The pattern is :
?subject ?predicate ?object
Line 10 specifies the condition for filtering the data. Here, these conditions are 'breadth is greater than 150 cm' and is 'breadth is conform to the Vademecum guidelines'.

Query 2: GeoSPARQL: Find the cyclingInfrastructure within 200m of Point of Interest (POI) in Turnhout

```
1.  PREFIX ogc: <http://www.opengis.net/ont/geosparql#>
2.  PREFIX geof: <http://www.opengis.net/def/function/geosparql/>
3.  PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
4.  PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
5.  PREFIX units: <http://www.opengis.net/def/uom/OGC/1.0/>
6.  PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
7.  PREFIX vmo: <http://www.verkeersveiligheidsmonitor.be/vocab/2015/CyclingInfrastructureOntology.owl#>
8.  PREFIX gn: <http://www.geonames.org/ontology#>
9.  PREFIX wgs84_pos:<http://www.w3.org/2003/01/geo/wgs84_pos#>
10. PREFIX spatial:<http://jena.apache.org/spatial#>

11. SELECT ?cycle_wkt_s

12. WHERE {

#conversion of lat long of katholieke-hogeschool-kempen-turnhout-gezondheidszorg to wkt
13. ?feature a gn:Feature ;
      a.  wgs84_pos:lat ?lat ;
      b.  wgs84_pos:long ?long .

14. BIND(spatial:toWKTPoint(?lat,?long) as ?wkt) .

#buffer point 200 m
15. BIND(geof:buffer(?wkt, 200, units:metre) as ?buffer) .

#find cycle tracks within Turnhout
16. ?cycletrack a vmo:CycleTrack;
           1.  ogc:hasGeometry ?cyclegeo.

#find cycle tracks within buffer
17. ?cyclegeo geof:sf_within[a ogc:Geometry;ogc:asWKT ?s_buff];
           i.  ogc:asWKT ?cycle_wkt_s.
18. }
```

Lines 1 - 10 provide the prefixes for the namespaces of ontologies used to describe the data.
Line 11 specifies the selection of variables we want to return as result. Here, these variables are the cycling infrastructure geometries with 200 m buffer distance
Lines 13 - 14 represent the conversion of latitude and longitude of Point of Interest (POI), being here katholieke-hogeschool-kempen-turnhout-gezondheidszorg to a WKT variable using a Spatial function (spatial:toWKTPoint).
Line 15 uses the GEOSPARQL function geof:buffer to create a buffer around the POI.
Lines 16 - 18 present the selection of the cycling infrastructure with the buffer by using GEOSPARQL function geof:sf_within.

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[32] http://geojson.org/
[33] The Vademecum Fietsvoorzieningen is available at: http://www.mobielvlaanderen.be/vademecums/vademecumfiets01.php

5 DISCUSSION

5.1 Challenges in LOD

During the recent years, there has been a significant increase in the availability of large amounts of open, distributed and structured semantic data on the web. At the same time, there have been important advances in semantic search (Baines and Lightfoot, 2009; Lopez et al., 2013). Linked (Open) Data fundamentally advocates the interoperability and reuse of data. However, there are considerable challenges, drawbacks and possible hurdles in realizing the full potential of Linked Data (Bechhofer et al., 2013; Lopez et al., 2010). Linked Data principles are built on a stack of several standards and technologies. The learning process is long owing to complexity of the Semantic Web for researchers and developers. The end-users can benefit from Linked Open Data only if there are user-friendly interface solutions that conceal the complexity underneath. Also, the process of finding and querying the distributed semantic open data are difficult and not optimal (Bechhofer et al., 2013; Lopez et al., 2010). Also, to ensure the reusability of the open data, metadata is crucially important as it provides information about provenance, quality, credit and methodology. The issue of trust could be minimized only if the user can view and explore metadata. The assessment of data quality is yet another issue to be solved. There is no automated method to know if the links are logically consistent. Also the misuse of Linked data or misrepresentation of information within Linked data may direct semantic search engines or Semantic Web applications to a spammer's data or website (Hart and Dolbear, 2013).

5.2 Lesson Leaned in the context of Geospatial LOD

In the traffic safety monitor, the linked open data case was implemented to standardize metadata and spatial indicators to give more insight about the traffic safety. The focus lied at the development of a business process for the semantic exchange of spatial data and metadata using linked open data principles. This business process allows describing spatial indicators in a structured way as well as unlocking and presenting them in a coherent way to ensure exchangeability of indicators through semantic operability. The same BPMN workflow can be used for conversion of any other spatial data. The improvisation of the process and semi-automatisation some process is forseen in future. The publication tool 'Parliament' triple store succesfully carried out the simple geoprocessing functions such as buffer and intersects. This should be considered as the strength of the store as it implements the GeoSPARQL standards. The workflow still does not include the interlinking and enriching part of the process.

The geospatial semantic web can offer more intelligence to spatial reasoning and increase the benefit of LOD with geospatial information. It still is at initial stage of development however, facing several challenges in the implementation. The first challenge encountered while developing the workflow is finding stable software. Most of the software packages that are available for free are still a prototype version. Consequently, they are not stable enough to put into production. Performance issues with such software tools include problems of crashing while running queries. A second issue with the geospatial semantic web is that different types of software tend to use their own vocabularies for representing geometries. This makes it more difficult to understand and use them. Although, LOD advocates the reuse of ontologies, the new vocabularies are still being developed. Sometimes it is understandable as Geospatial LOD is not extensive enough to cover all the vocabularies in different domain. However, even the basic vocabularies for representing point geometries is varies for different softwares. Even GeoSPARQL, an W3C recommendation, is supported only by a few softwares. This makes it difficult to achieve the vision of the semantic web where everybody is speaking the same language. The support for map visualization and spatial analysis tools for end users is a third issue. The visualization of linked geospatial data in most case is currently very primitive (for example, restricted to point geometry). Some tools are map4rdf, mappify are still under development.

The installation of different softwares for each phase like mapping tool, converting software, publishing software and visualization software made a conversion and consumption of LOD a cumbersome process. The need for an integrated platform for gespatial data was realized. The GeoLinked data project had develped such platform 'GeoKnow generator workbench' (Garcia-rojas et al. 2014). The tool did not yet support GeoSPARQL and had only point geometry visualization. The GeoSpatial field has still long way to go to develop stable and harmonized solution for Geospatial LOD.

5.3 Coming back to smart mobility : the road ahead

Smart cities concept seems to be divided into two major themes: used of wide range of smart applications (ICT driven) and cititzens and government making sustainable livelihood and environmental choices (citizen driven) (Beniamino Murgante & Borruso 2015). The common grounds here are open data, cross-sector interoperability and user driven application (Bork et al. 2015; Bastiaan Baccarne et al. 2014). In terms of smart mobility the alternative sustainable modes to the private vehicles such as cycling is a needed approach (Garau et al. 2015; Garau et al. 2016). For intercommunication, sharing and processing of the data it is emminent that everybody is speaking the same language. Linked Open Data priciples provides the set of standards for the harmonisation. Linked open data can aid in achieving smart mobility by combining the data from the different sources giving new insights to the situation (Janssen et al. 2011; Kyzirakos et al. 2014; Kyzirakos et al. 2012; Khusro et al. 2014).

In the evolution towards the 'Mobility monitor' from the 'Traffic safety montitor, the cycling infrastructure data will be available for downloading using OGC standardised web services WFS. The data will be available as RDF. The future research further explore the suitability of cycling tracks for mobility scooters, bicycle trailers etc. In the context of indicator development focus is on linking the cycling infrastructure data to other interesting external datasets. The other spatial indicators related to accessibility, road safety, reachability, liveability and environment will be available to public as Geospatial LOD. The aim here is to promote the use of Geospatial LOD and provied an opportunity to connect to the extenal sources, in turn opening the door to the innovation and ad-hoc applications. We give one example of such application as the potential of Geospatial LOD. In our case, the research started with the conversion of the cycling infrastructure to LOD. The focus here is the saftey of citizen while cycling. Along with the infrastructure, another aspect of bikers safety is reducing the number of deadly/non-injurious accidents. The death with accident involving cyclist are officially registered but it is equally interesting to know from citizens point of view which cycling tracks are considered dangerous. These type of accidents though not registered in the accident database of the government but could be gathered via 'crowd sourcing'. Citizen might be intereseted to know about the deadly points in the road and be warned beforehand. Here, LOD is crucial for ensuring interoperability of the data coming from the heteregenous sources. The smart mobile application an help to do the predictive analysis and provide the possible safest cycling routes.

6 CONCLUSION

We are confronted with the challenge of the reducing the traffic jams, accidents and ensuring the safety of the citizens while commuting. In Belgium, cyclists are the major component of the traffic and often considered vulneratble traffic victims. In terms of smart mobility, the clean energy and reducing the traffic cyclists can play major roles. Here, Linked (Open) Data certainly holds a promising future. Also, it helps to overcome expensive costs of data harmonization and processing. The fundamental principle of Linked Data is to make data open and available on the web, maximizing its use, reuse and innovation.

However, Geospatial LOD is still at intial phase, most of the software supporting only two point geometries. Also, the software tools to support link discovery and data reuse are relatively immature since the technologies are on the frontline of development. Another aspect is that Linked Open Data is a combination of stack of technologies. There is a need to install specific software for mapping, creating ontology, storing and client side application. To promote the use of LOD as general, there is a need for an integrated platform with stable release. In our experience, it becomes a long learning process if there is necessity to understand and install and use several process. And, the issue of semantics still remains if everybody is working in own silos and developing. Another important expect is reuse of the data. The end-users are expected to benefit the most of Linked Data via user friendly web applications, since query developments are a barrier for people with less technical expertise. The technologies being relatively new has still some hurdles to overcome.

In this study, we formulated a standardized business process model for converting "cycling infrastructure data" to simplify the Geospatial LOD conversion process. The BPMN process need to be extended to include interlinking and enriching phase of Geospatial LOD in the future. In the evolution towards the Mobility monitor, the focus lies in liniking to external dastasets such as environmental and vehicular data to gain maximum insight. The research aims at promoting smart mobility applications and decisions. The objective is to promote both Open Data via WMS/WFS (5) and 5 stars of Tim Berneers Lee Geospatial Linked Open Data.

7 ACKNOWLEDGEMENTS

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