School of Earth and Planetary Sciences

Automatic Geospatial Data Conflation Using Semantic Web Technologies

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

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ABSTRACT

In Australia, duplicate geospatial data collections and maintenance are an extensive problem across government organisations. They include local government authorities, State/Territory government departments and commonwealth agencies. The vast majority of spatial data is acquired at the local government level from various suppliers. Local governments process heterogeneous sources to generate value-added products for their own business needs and customers, as well as contributing to State or Territory level datasets. The same processes are applied by State and Territory governments to their datasets before being supplied to national aggregators to produce nationwide datasets. This is the current status of national Spatial Data Supply Chains (SDSCs) in Australia.

Duplication of spatial data often occurs at several points along the SDSCs where methods, models and workflows are applied to process or add value to spatial data to meet specific agency business needs. Many processes are manual and undocumented and there is a significance reliance on human expertise and intervention. Often duplication occurs through lack of awareness that data already exists, or because no single dataset can suit the needs of multiple agencies.

There are many issues regarding this situation: data is captured repeatedly, redundant datasets are available that are often inconsistent, and there is a consequent inefficient use of resources. These lead to questions concerning which dataset is the most accurate, complete and current. To streamline the SDSC and enhance collaborative data management among agencies, it is desirable to have a conflated dataset, which is a combination of few datasets, that is the single point of truth dataset and most suitable to the needs of customers.

This research is targeting problems associated with geospatial data conflation through the development of an Automatic Geospatial Data Conflation (AGDC) system. The research examines how Semantic Web technologies, specifically Resource Description Framework (RDF), Web Ontology Language (OWL) ontologies and Semantic Web Rule Language (SWRL) rules, can be used to automate the geospatial data conflation process. This research presents a new approach to geospatial data conflation where OWL ontologies are generated based on output data models and geospatial data are presented as RDF triples. A set of SWRL rules are generated and used in a sequential order to model human experts' logic in order to find the most accurate or fit-for-purpose location, remove duplicate features and conflate the remaining attributes into a single location. Both OWL ontologies and RDF triples serve as the basis for the solution and SWRL rules serve as the core to automate the entire geospatial data conflation processes. In this way, the conflation processes can be run automatically without human intervention.

The method is demonstrated by showcasing how three Points of Interest (POI) datasets can be conflated into a single dataset. The implementation consists of four stages. Stage 1 is the creation of an ontology based on a multipurpose data model. The multipurpose data model is one that can be used by government agencies for various business purposes. Stage 2, refers to the conversion of disparate source datasets into the RDF format so they can link to the ontology during the conversion; and the development of SWRL rules to align attributes from the various sources so they can be more readily compared and assessed in the latter stages of the conflation process. Stage 3 uses location proxy and other similarity measurements based on semantic descriptions to find matching candidates across datasets. Stage 4 uses a reasoning process to model how domain experts make decisions on which feature attribute values are the best or most accurate when they are considering various data sources. A conflated POI dataset reduces duplicates and improves the accuracy and confidence of POIs thus increasing the ability of emergency services agencies to respond quickly and correctly to emergency callouts where times are critical.

The uniqueness of the method proposed in this research is that the method models users' analytic and reasoning steps to automate spatial data integration processes. The method provides the user with the flexibility to combine various knowledge sources, such as provenance, topological relationships, policies, business rules and user experiences, so that geospatial dataset integration can be tailored to serve a specific application purpose. Additionally, the need for user intervention is reduced once integration steps have been designed and the process can be run automatically.

LIST OF ACRONYMS

AGDC	Automatic Geospatial Data Conflation
ANZLIC	Australian and New Zealand Land Information Council
ANZSM	Australian and New Zealand Spatial Marketplace
API	Application Programming Interface
CRCSI	Cooperative Research Centre for Spatial Information
CRS	Coordinate Reference Systems
CSV	Comma-Separated Values
CSW	Catalogue Service for the Web
DBMS	Database Management System
DCCM	Data Conflation Conceptual Model
DFES	Department of Fire and Emergency Services
DL	Description Logic
DTD	Document Type Definition
EO	Earth Observation
ESRI	Environmental Systems Research Institute, Inc.
ETL	Extract-Transform-Load
FSDF	Foundation Spatial Data Framework
Geo XG	W3C Geospatial Incubator Group
GeoJSON	Geographic JSON
GIS	Geographic Information System
GML	Geography Markup Language
GSDI	Global Spatial Data Infrastructure
GUI	Graphic User Interface
HTTP	Hypertext Transfer Protocol
IETF	Internet Engineering Task Force
IRI	International Resource Identifier
ISO	International Standards Organization
ISO/TC 211	International Standards Organization / Technical Committee 211
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
Landgate	Western Australian Land Information Authority

LD	Liked Data
LOD	Linked Open Data
NSDI	National Spatial Data Infrastructure
OBDA	Ontology-based Data Access
ODGIS	Ontology-driven Geographic Information System
OGC	Open Geospatial Consortium
ORDBMS	Object-Relational Database Management System
OSM	Open Street Map
OWL	Web Ontology Language
OWL-S	Semantic Markup for Web Services
POI	Point of Interest
RCC	Region Connection Calculus
RDBMS	Relational Database Management System
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
RML	RDF Mapping Language
RSS	Really Simple Syndication
SDI	Spatial Data Infrastructures
SDSC	Spatial Data Supply Chain
SOA	Service-Oriented Architecture
SPARQL	SPARQL Protocol and RDF Query Language
SQL	Structured Query Language
SVG	Scalable Vector Graphics
SW	Semantic Web
SWIG	W3C Semantic Web Interest Group
SWRL	Semantic Web Rule Language
UML	Unified Modelling Language
URI	Unique Resource Identifier
URL	Uniform Resource Locator
W3C	World Wide Web Consortium
WAPOL	Western Australian Police
WCS	Web Coverage Services
WFS	Web Feature Service

WGS84	World Geodetic System 1984
WKT	Well-Known Text
WMS	Web Map Services
WWW	World Wide Web
XML	Extensible Markup Language

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1 INTRODUCTION

1. 1 Duplicated Geospatial Data across Australia National Spatial Data Supply Chain

Spatial Data Infrastructures (SDI) is "the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data" (The White House, 2002). Australia was one of the leading countries to recognise the importance of SDI and put significant effort into developing a National Spatial Data Infrastructure since the mid-1990s (ANZLIC, 2014; Chan, West, McMeekin, Woodgate, & Loughrey, 2013; Jacoby, Smith, Ting, & Williamson, 2002; McMeekin & West, 2012; Nairn, 2000; Warnest, Rajabifard, & Williamson, 2002; Waterhouse, 1995; Williamson, Rajabifard, & Binns, 2007). Like any other national infrastructure, SDI plays a crucial part to Australia's society and economy. Government users use spatial data to facilitate decision making and make informed policies. The private sector uses spatial data to understand customer distributions, analyse potential customer locations and inform better business decisions. Between 2006-07, a conservative estimate of the spatial information industry revenue was $1.37 billion, and the industry's gross value added product was an estimated $682 million to the Australian economy (ACILTasman, 2008).

There are increasing needs of government and non-government organisations as well as individual users from various industries to gain access and easy use of high quality and timely spatial data across Australia. The Foundation Spatial Data Framework (FDSF) which contains 10 distinct themes of foundation level spatial data (Administrative Boundaries, Elevation and Depth, Geocoded Addressing, Imagery, Land Cover and Land Use, Land Parcel and Property, Place Names, Positioning, Transport, and Water) is intended to meet the increased demand to deliver the "best available, most current, authoritative source of foundation spatial data which is standardised and quality controlled" across Australia (ANZLIC, 2014). To achieve such national spatial data outcomes, the key challenges are not data shortage but the opposite, too much overlapping data available from different levels of government (Box, Simons, Cox, & Maguire, 2015; CRCSI, 2015; Van der Vlugt, 2012), leading to the complex and daunting integration processes of producing national datasets.

In Australia, duplicate geospatial data collections and maintenance are extensive problems across government organisations. They include local government authorities, State/Territory government departments and commonwealth agencies. The vast majority of spatial data is acquired at the local government level from various suppliers. Local governments process heterogeneous sources to generate value-added products for their own business needs and customers as well as contributing to State or Territory level datasets. The same processes are applied to State and Territory level datasets before being supplied to national aggregators to produce nationwide datasets.

This is the current status of national Spatial Data Supply Chains (SDSCs) in Australia as described in Figure 1.1. The SDSC, which stems from the supply chain concept in the manufacturing industry was used to depict the flow of raw spatial data via processing through to the end customer as a product (L. Arnold, 2016). Duplication of spatial data often occurs at several points along the SDSCs where methods, models and workflows are applied to process or add value to spatial data to meet specific agency business needs. Many processes are manual and undocumented and there is a significant reliance on human expertise and intervention (P. Varadharajulu et al., 2015). Often duplication occurs through lack of awareness that data already exists, or because no single dataset can suit the needs of multiple agencies.

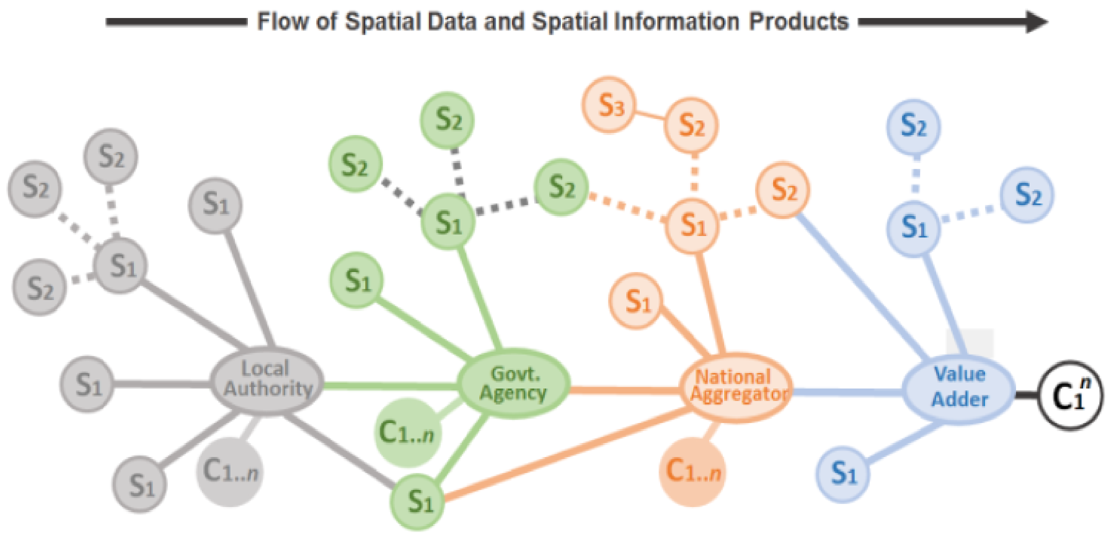

Figure 1.1 Linear national spatial data supply chain where S = Supplier Tiers (1...n) and C = Customer Tiers (1...n). (L. Arnold, 2016)

There are many issues regarding this situation: data is captured repeatedly, redundant datasets are available that are often inconsistent, and there is a consequent inefficient use of resources. These lead to questions concerning which dataset is the most accurate, complete and current. To streamline the SDSC and enhance collaborative data management among agencies, it is desirable to have a conflated dataset, which is a combination of few datasets, that is the single point of truth dataset and most suitable to the needs of customers.

1. 2 Streamline SDSC via Automatic Geospatial Data Conflation

This research is targeting problems associated with geospatial data conflation through the development of an Automatic Geospatial Data Conflation (AGDC) system. The AGDC is a much-needed solution towards improving the entire SDSC process. The aim is to conflate overlapping data sources into one single authoritative and trusted dataset that can satisfy multiple purposes and be co-maintained by multiple organisations. It can be a permanent-stored dataset that has the most accurate position information among datasets and combines all available attributes from each source dataset. Multiple agencies can co-maintain this dataset instead of maintaining their own source data, therefore reducing the duplication of effort along the SDSC, improving efficiency and reducing cost. Alternatively, the conflation process can be applied "on-the-fly". Users search relevant data sources online (e.g. by a query) and the rules are invoked based on their needs. The conflation process is then triggered by the user query.

This research explores how developments in Semantic Web (SW) research can be used to automate the conflation process. The SW was originally proposed by Berners-Lee (1998) as a way to promote the sharing and use of the enormous amount of data and information on the World Wide Web (WWW)[1]. It relies on the HTTP[2] protocol and Uniform Resource Locator (URL)[3] for access and more flexible representations of data to allow linking and reasoning to extract knowledge. Data is recommended to be available in the Resource Description Framework (RDF)[4] format (object, predicate, value) triples that can be used to represent data as graphs, trees i.e. linked data. More recently languages such as OWL-2 (Ontology Web Language)[5] have been proposed that allow data, axioms, constraints and rules to be represented in RDF, in the same or different files to enable more complex representations and processing. The Semantic Web Rule Language (SWRL)[6], a form of Description Logic (DL)[7], can be used to infer new knowledge from OWL-2 files, much like a human expert can infer new knowledge from existing information. Importantly OWL-2 files are text-based, follow well defined schema, are separate from the software required to process them, and hence can be published and used by others instead of being buried in programming code. These specific technologies are developed based on the foundation blocks such as RDF, Ontology and Rules which can be found on the Semantic Web Technologies Stack (Berners-Lee, 2000), see

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[1] Also referred as 'the Web' in this thesis.

[2] The Hypertext Transfer Protocol (HTTP) is an application-level protocol for distributed, collaborative, hypermedia information systems. It is a generic, stateless, protocol which can be used for many tasks beyond its use for hypertext, such as name servers and distributed object management systems, through extension of its request methods, error codes and headers. https://www.w3.org/Protocols/HTTP/1.1/rfc2616bis/draft-lafon-rfc2616bis-03.html

[3] A Uniform Resource Locator (URL), colloquially termed a web address, is a reference to a web resource that specifies its location on a computer network and a mechanism for retrieving it.

[4] RDF is a standard model for data interchange on the Web. http://www.w3.org/RDF/

[5] The OWL 2 Web Ontology Language, informally OWL 2, is an ontology language for the Semantic Web with formally defined meaning. http://www.w3.org/TR/owl-overview/

[6] https://www.w3.org/Submission/SWRL/

[7] https://en.wikipedia.org/wiki/Description_logic

Figure 1.2. The Stack illustrates the hierarchy of the SW showing it's not a replacement but an extension of the classical hypertext Web as the bottom two layers on the stack are technologies (i.e. Unicode, URI, XML and XML Namespaces) that also underpin the hypertext Web. RDF, Ontology and Rules are all on top of the basis technologies and each of them exploits and uses the layer capabilities below them. The Stack shows how these technologies are organised to develop SW. It is an evolving environment as the stack components are developing (Machado, Souza, & da Graça Simões, 2018).

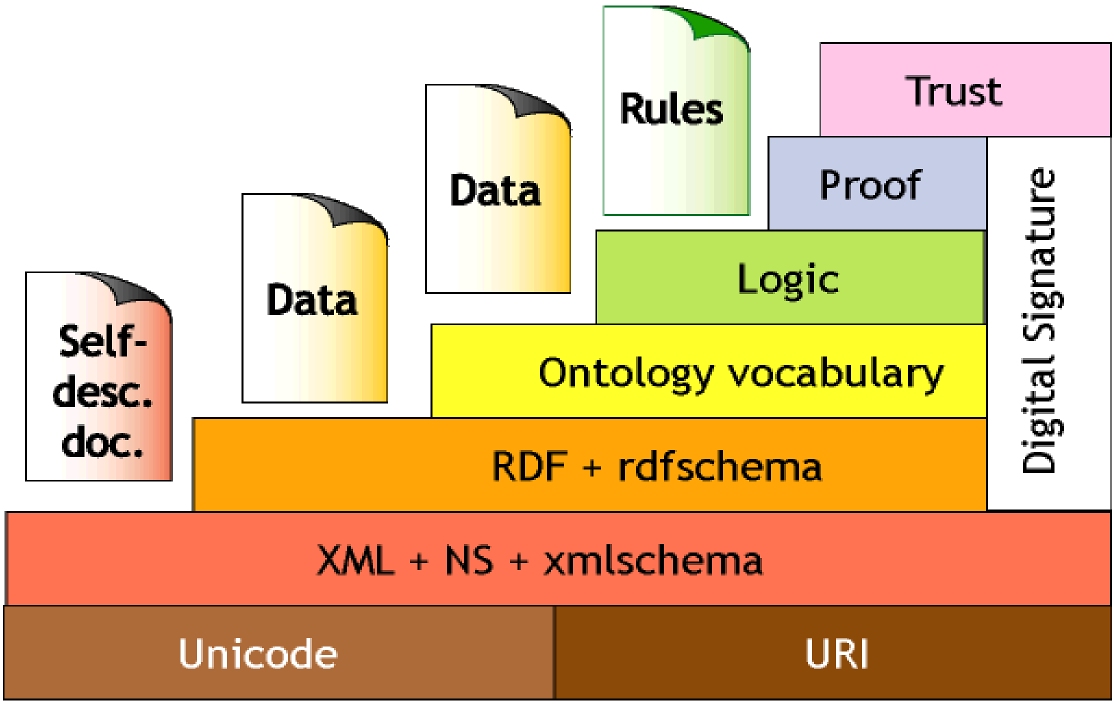

Figure 1.2 Semantic Web Technologies Stack by Tim Berners-Lee (Berners-Lee, 2000)

1. 3 Research Objectives

This research focuses on building ontologies from multiple heterogeneous spatial datasets and creating relevant SWRL rules, which for example, can be used to replace human reasoning procedures so as to reduce human intervention as well as transform the requirements of multiple agencies into machine readable forms that are based on multiple knowledge domains, such as geometry, topology, policies, business rules and expert experiences. These rules are then used in reasoning processes to realise filtering, matching and integrating data intelligently.

Overall, the research seeks to answer the following questions:

(a) How to define an output data model fit for multiple purposes based on multiple input data sources and how to generate a suitable ontology accordingly?
(b) How to access databases based on ontology and mapping data to RDF triples, so all input datasets are in a common format and ready to be integrated?
(c) How to run initial data filtering so homologous elements can be identified and matched?
(d) How to automatically realise dataset alignment? How to store the conflated datasets in multiple representations to fulfil different user needs?

In answering these questions, the research project has following objectives:

(a) Objective 1: Investigate and identify standard data models that can be used as conflation output data models that are fit for multiple agencies' purposes in Australia.
(b) Objective 2: Investigate appropriate geospatial ontologies structures and creation methods for guiding the generation of ontologies that can meet conflation process needs.
(c) Objective 3: Review existing tools available for transforming and managing traditional geospatial data in RDF format.
(d) Objective 4: Develop methodologies for creating SWRL rules that can automate the geospatial data conflation process.
(e) Objective 5: Evaluate the geospatial data conflation conceptual framework based on a case study.
(f) Objective 6: Develop a Proof of Concept application as a demonstrator of the research concept and process.

1. 4 Significance of the Research

Previous research shows that there are many benefits to data conflation. Stankutė and Asche (2011) proposed improving spatial data quality including completeness, logical consistency, positional/geometrical accuracy, temporal accuracy and attribute accuracy by using data conflation. Uitermark, van Oosterom, Mars, and Molenaar (1999) studied data integration to develop an update propagation system, so updates can be reused in different datasets. Wache et al. (2001) believed data integration was the way towards efficient information sharing. Data conflation has also been studied in the context of Spatial Data Infrastructure (SDI) to enhance available spatial information (Wiemann & Bernard, 2010) and ensure effective access and reuse of spatial data (Mohammadi, Rajabifard, & Williamson, 2008).

This research focuses on automatic data conflation that is a much-needed solution towards improving the entire Spatial Data Supply Chain process. In Australia, there are many organisations that acquire data for specific areas or points of interest. Data conflation is the process of combining these overlapping multiple data sources together to build one single point of truth dataset while retaining accuracy, reduce redundancy, reconcile data conflicts and obtain richer attributes. The conflated dataset is then used as the single source, authoritative and trusted dataset fit for multiple purposes that can be co-maintained by multiple organisations. All in all, the conflation process can reduce the duplication of effort along the Spatial Data Supply Chain, improve efficiency and reduce costs.

Duplicate datasets are not uncommon across Australia; from local government authorities to state government departments to commonwealth agencies, data duplication exists at each stage of the Spatial Data Supply Chain. An example, the LOC8WA project managed by Landgate (Western Australian Land Information Authority) in collaboration with the DFES (Department of Fire and Emergency Services) and the WAPOL (Western Australian Police), demonstrates significant duplication in the collection of Point of Interest (POI) data. WAPOL collects and processes a set of POI data from various authoritative sources covering objects such as political offices, schools, railway stations and other business premises. Similarly, DFES collect another POI dataset of different and similar objects from similar or different sources. Landgate also collects POI data. According to Simon Abbot (LOC8WA Project Manager) the annual cost to WAPOL is over \$100,000 and the cost to DFES is similar. This is in addition to the resources used to build the Landgate POI dataset.

Being able to easily conflate these data will improve efficiency during the acquisition and maintenance of POI data for emergency management within Western Australia. By integrating datasets from DFES, WAPOL and Landgate, the accuracy and confidence of emergency location information may improve and this in turn increases the ability of emergency services to respond quickly and correctly. Through these efforts, lives may be saved and property damage minimised. The cost to collect and maintain duplicate datasets across these departments may also decrease. Given that data duplication and information inconsistency (currency and accuracy) is prevalent across the spatial sector, nationally, the benefits to the economy and wellbeing of citizens may also be significant.

In 2006-07, a conservative estimate of the spatial information industry revenue was $1.37 billion, and the industry's gross value added approximately $682 million to the Australian economy (ACILTasman, 2008). The economic impact of the spatial information industry is more than this because most sectors of the economy including households, investments and imports, increasingly use spatial information which has a direct impact on productivity. Therefore, this research has the potential to significantly benefit the nation economically through improved information for the broader community.

1. 5 Research Method

This research will make use of the advanced SW technologies to realise the automatic data conflation process. The Research Methodology includes the following aspects:

(a) Literature review
(b) Conceptualise the model
(c) Build the model
(d) Evaluate/test the model

1.5.1 Literature review

A comprehensive literature review regarding SW technologies, geospatial data conflation/integration systems and the utilisation of SW technologies in the geospatial integration domain will form the basis for guiding development in this research. Continuous journal and research paper reviewing during the research will be carried out to ensure currency with the research progress in this area so that no duplicate effort is wasted into research which has already been done.

1.5.2 Cconceptualise model

The proposed Data Conflation Conceptual Model (DCCM) is presented in Figure 1.3 and includes the following:

(a) Stage 1: Preliminary analysis of heterogeneous source datasets and different user needs are considered to formulate the output data model which needs to meet multiple purposes. Ontologies are then generated accordingly.

(b) Stage 2: Datasets are accessed, and data instances are mapped to ontologies and stored in RDF triple format. In this way all data are in a common format and ready for initial filtering in Stage 3 and reasoning process in Stage 4.

(c) Stage 3: An initial filter based on location proxy and address similarity is run to determine which elements are homologous elements and which elements are not. No corresponding elements are stored at this stage as they will be conflated later.

(d) Stage 4: A comprehensive reasoning process is run among homologous elements in order to get the best location (spatial accuracy) and richest attributes (feature characteristics). The reasoning results, together with those elements that do not correspond, are then exported as a single conflated dataset.

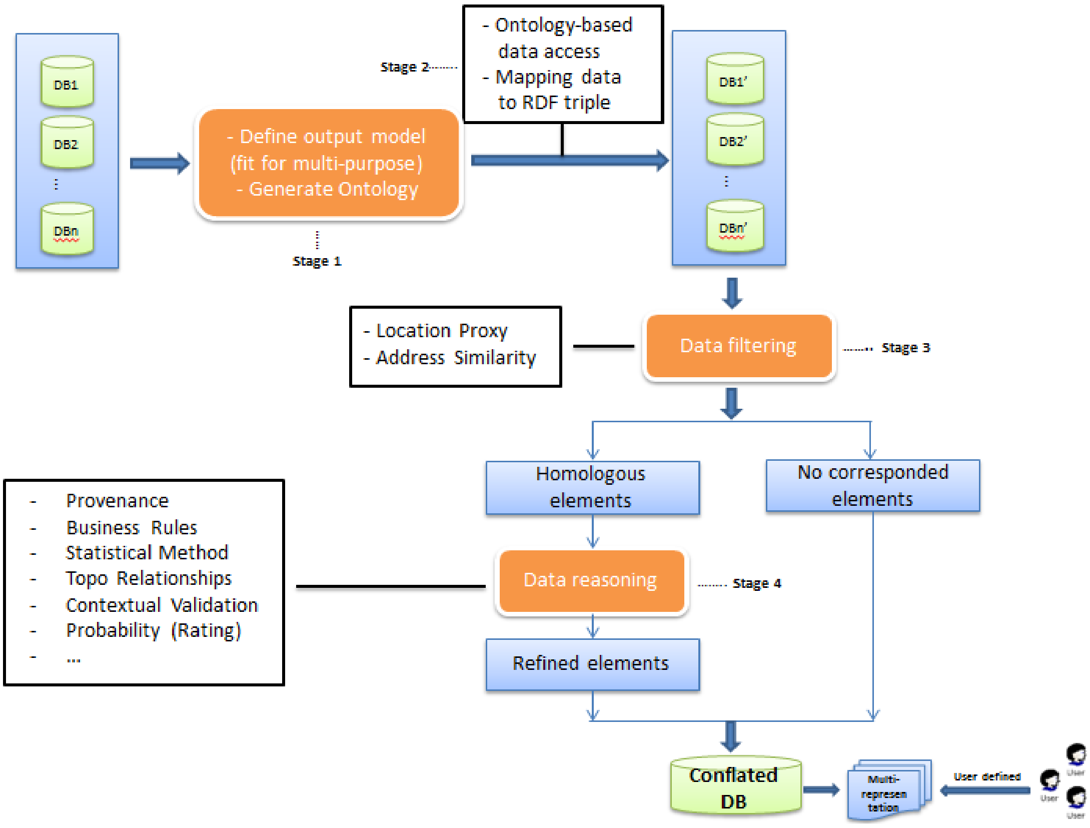

Figure 1.3 Geospatial Data Conflation Conceptual Model

1.5.3 Building the model

A case study is used to develop a prototype system based on the conceptual model. The process is designed into four stages as below:

(a) Stage 1: Define output model and generate ontologies accordingly

The first step is defining a fit for a multi-purpose output model which is also a very important step for this conflation process. The data model represents the multi-purpose model that meets the business needs of the participating agencies. The output model can affect the reasoning procedure design later on. For example, different models can define which data is ruled out first and the final decision will differ accordingly. However, this research is not planning to define a completely new model from scratch; instead, the research will exploit existing models and contribute to the model evolution whenever possible. For example, the best data model among the resource datasets will be used or the commonly accepted standard model will be expanded. For example, in the LOC8WA project Landgate's POI data model will be used because the source datasets are within a same data theme. Alternatively, for future project where source datasets are from different data themes, the project can use data models from the national Foundation Spatial Data Framework, which are the proposed Australian standard data models, such as the Roads Data Model for Transport theme datasets (ANZLIC, 2014); or data models from the Open Geospatial Consortium (OGC) and International Standards Organization (ISO), such as OGC® IndoorGML standard which specifies an open data model and XML schema for indoor spatial information (OpenGeospatialConsortium, 2014).

The ontology generation starts from the output model which acts as a global schema and then can be expanded to accommodate various sources of datasets. These ontologies are a set of conceptual specifications of the domain of interest. They are an expression of the data structures that contain rich semantic descriptions about the relevant concepts and relationships within the application domain. The way the ontologies will be created is consistent with the method proposed by Ghawi and Cullot (2009). They propose building ontologies from several information sources in the schema-merging-based approach. Therefore, the target ontology is created from a unified schema and the extension of existing mappings between each source and the ontology. Advantages of this method are that mappings between ontology components and database components are quite direct and the ontology creation process is straightforward. The drawback is that these direct mappings may not be sufficient enough to express the full semantics. Additional semantic relations between data components need to be discovered and used to create ontology concepts and relations (Ghawi & Cullot, 2007). The ontology generation method applied in this research is a combination of a direct mapping process and additional use of SWRL rules to infer further semantic relations, so that the drawback of the direct mapping method can be overcome.

In this research, the direct mapping approach is used to generate classes and class instances directly from concepts in an output data model. Object properties and data properties are defined to express explicit semantic relations between classes and class instances. In addition, SWRL rules are created to infer further semantic relations which are implicitly expressed in the data model. The rules together with classes, class instances, object properties and data properties form the top-level ontology that is created based on the data model. The top-level ontology contains the minimum information required to express the essential knowledge of a domain of interest and can be expanded to deal with a specific project or application.

(b) Stage 2: Access data based on ontology and mapping data into RDF format

Ontology-based data access (OBDA) uses an ontology as a high-level conceptual view over data repositories originally proposed by Calvanese *et al.* (2011) for their system MASTRO. The OBDA system is a three-level architecture: (i) ontology; (ii) the data sources; and (iii) the mapping between them. The ontology can be seen as the system user interface, and mapping relates ontology elements to the corresponding data source.

MASTRO has been shown to be a successful OBDA system through series demonstrations (Calvanese et al., 2011; Poggi et al., 2008; Rodriguez-Muro, Lubyte, & Calvanese, 2008; Savo et al., 2010). This system fulfils ontology-based data access through four modules, including the Ontology Definition Module, which is the mechanism to describe data sources into ontologies; Mapping Manager for building mapping assertions between the concepts in the ontology and the corresponding elements at the sources; a Data Source Manager that communicates among the underlying relational data sources, and together with Mapping Manager provides access to various relational Database Management Systems (DBMS); and a Reasoner which answers user's queries and displays the results. In such a way, the facilities offered by Protégé[8] can be used for ontology editing as well as functionalities provided by the OBDA plugin used for editing mappings to external data sources.

Once the mapping is established, it can be used to generate RDF triples. There are many tools available to convert a database to corresponding triples in the literature. Bizer and Cyganiak (2006) proposed the D2R (Database to RDF) tool which can easily generate RDF triples from relational databases. The D2R tool uses table names as class names and column names as property names. Craig A Knoblock et al. (2011) and his team developed Karma, an open source data integration tool that allows users to quickly integrate data from various data sources. Through a series of articles (Gupta et al., 2012; Craig A Knoblock et al., 2011; Szekely, Knoblock, Gupta, Taheriyan, & Wu, 2011; Tuchinda, Szekely, & Knoblock, 2008) , they demonstrate that with the Karma tool, users can map structured data into RDF triples based on the given ontology. Mappings can be seen through the Karma interface and users can adjust them if necessary.

(c) Stage 3: Initial data filtering

One of the most important attributes of a spatial entity is location. If we have the latitude/longitude property or a unique identifier, such as an address, we can establish uniqueness of a location (Adams, Li, Raubal, & Goodchild, 2010). So, an initial data filtering based on location proxy and address similarity can identify a list of corresponded candidates. These candidates will then be carried into the next step for a more sophisticated reasoning to determine whether they are truly matched or to decide which location is the best.

(d) Stage 4: Data reasoning

The design of the data reasoning process is the core of this research. How to use the many sources and types of knowledge to formulate rules in a machine-readable way so that it minimises human intervention through automatic processes; and how to

[8] https://protege.stanford.edu/

combine these rules in a proper sequence to get the best quality from the reasoning. These are the major questions tackled in this research. Types of knowledge to be used are:

(i) Data provenance: the description of the origin of a piece of data and process by which it arrived in a database (Buneman, Khanna, & Tan, 2001). According to the World Wide Web Consortium[9] (W3C) definition (W3C, 2015), it provides a critical foundation for assessing authenticity, enabling trust and improving reliability (Madden et al., 2011).

(ii) Business rules: the specification of user defined rules which are part of the database design process (Cockcroft, 1998). Databases normally have certain integrity constraints with respect to the data in order to ensure data quality. So, by means of writing business rules in a machine-readable format, the proposed reasoning mechanism can automatically decide which dataset quality is better based on the business rule. Formalised domain expert experience can also form part of business rules. Topological constraints are aspects of the business rules as well.

(iii) Statistical methods: for example, if several coordinates represent the same spatial entity or POI, without other conditions to help, methods are needed to decide the best one to choose. The reasoning process might have to use a simple statistical method to calculate the location, such as either at the mean, median or mode position.

(iv) Contextual validation: use aerial photography or satellite imagery to validate information.

(v) Probability/Rating: making a decision based on how likely an event will occur or evaluate information and give it a rating, and then making a decision based on the highest rating.

1.5.4 Evaluate/test the model

To the best of our knowledge, using SW technology in geospatial data conflation as described, has not been done previously, making this research novel and a significant contribution. So, there is no opportunity for comparison with other systems. Hence

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[9] The World Wide Web Consortium (W3C) is an international community that develops open standards to ensure the long-term growth of the Web. https://www.w3.org/

the only approach is to self-test the model and methods developed. Since the current methods for data conflation are mainly manual, the model will be evaluated to determine what extent automated processes can be realised. The resulting accuracy will be tested and compared against conflated results achieved today using manual methods.

1. 6 Thesis Structure

This thesis is organised into seven chapters outlined as followed:

Chapter One introduces the current duplicate geospatial data status across Australian national spatial data supply chains, which hinders the effectiveness of producing national spatial data infrastructure datasets and why an AGDC system is essential to streamline SDSCs. The research aims and objectives are defined in this chapter as well as the research significance. Methodologies to achieve an AGDC system using SW technologies are also introduced.

Chapter Two is the literature review, which depicts an overview about the status of geospatial data integration and conflation. State of the art of geospatial data conflation/integration methods are reviewed especially methods involving SW technologies.

Chapter Three focuses on the foundation of SW technology – Resource Description Framework (RDF). It explains the advantage of the RDF data format to resolve data heterogeneous issues and how geospatial data can be transformed to RDF and the management tools available for the geospatial RDF data.

Chapter Four explores the output data model which will be reviewed and adopted from the best available data models existing in Australian SDI or standards. It also examines one of the SW technologies i.e. ontology and methods regarding how to effectively generate ontologies based on the selected models.

Chapter Five is dedicated to the SWRL, which is the core of automatic geospatial data conflation.

Chapter Six demonstrates a case study and the evaluation of the proposed conflation method.

Chapter Seven concludes the research and discusses future research.

1. 7 Summary

This chapter introduces the key problem, aim and objectives of this research. The significance of the research is justified, and the research methodology is briefly described. The thesis structure has also been outlined in this chapter. A comprehensive literature review is presented in the next chapter.

2 LITERATURE REVIEW

2. 1 Introduction

"In GIS, conflation is defined as the processes of combining geographic information from overlapping sources so as to retain accurate data, minimize redundancy, and reconcile data conflicts." Longley (2005).

Data integration is "the process by which different sets of data within a GIS are made compatible with each other, so that they can be reasonably displayed on the same map and so that their relationships can be sensibly analysed" as quoted by Flowerdew (1991).

There is a tremendous number of geospatial datasets available across the Web (McMeekin & West, 2012; Y. Zhang, Chiang, Szekely, & Knoblock, 2013; Y. Zhang et al., 2016). Many of these datasets overlap to some extent, such as different thematic datasets covering the same geographic area; or the same thematic data, but with otherwise different accuracy levels and/or attributes e.g. attribute names or values, for the same area.

Data integration and conflation processes are used to combine these overlapping datasets to make them more reusable and more easily repurposed. For example, one typical requirement for making geospatial data more useable, is to combine multiple sources into an integrated view for better visualisation (Y. Zhang et al., 2013) and to support improved decision-making (Gupta & Knoblock, 2010). The process is normally referred as spatial data integration. Another type of geospatial data utilisation is to use two or more geospatial datasets to composite a new product, which can outperform any of the original sources because it has better positional accuracy and richer attributes (C.-C. Chen, Knoblock, & Shahabi, 2008; Hastings, 2008; Saalfeld, 1988; Samal, Seth, & Cueto, 2004). This process is defined as data conflation by Longley (Longley, 2005).

There is no clear separation between data integration and data conflation processes and there is mixed use of terms and concepts in contemporary literature. In this research, data conflation is considered as consistent with Longley's definition as it deals with bringing multiple source datasets into a unified view and aims to resolve conflicts between datasets, reduce duplications and achieve a more accurate dataset. Although varied in the final presentations, the process steps of data integration and data conflation are almost identical in the sub processes. First, data discovery is finding relevant sources fit for application requirements. Second, data retrieval is pulling all the discovered sources together from scatter locations. Third, data alignment is to smooth out the presentation differences between source datasets, which could differ in coordinate systems, data format, and data model or data schemas etc. Fourthly, data matching is identifying the records in each data source corresponding to the same real-world object. Finally, data integration is to provide a unified view for all data sources by linking and displaying matched records together; or data conflation to fuse all sources into a new dataset. Each step is not a simple mission and has been studied either as individual processing steps, such as data discovery (Parekh, Gwo, & Finin, 2004), data retrieval (Walter & Fritsch, 1999), data matching and linking separately (Sehgal, Getoor, & Viechnicki, 2006; Wiegand & García, 2007) or have been studied in a composite way (series of steps) (Cavazzi et al., 2015; Giannopoulos, Skoutas, Maroulis, Karagiannakis, & Athanasiou, 2014; Giannopoulos, Vitsas, Karagiannakis, Skoutas, & Athanasiou, 2015; Y. Zhang et al., 2013; Y. Zhang et al., 2016). Either way, the goal is to realise the final step, which is to more efficiently (or automatically) achieve a more accurate data resource.

2. 2 Moving from Digital Map Conflation to Geospatial Data Conflation

2.2.1 Digital Map Conflation

"Conflation of maps refers to a combining of two digital map files to produce a third map file which is "better" than each of the component source maps." Lynch and Saalfeld (1985).

It is well recognised in the spatial data domain that Lynch and Saalfeld (1985) were the first to make map conflation a reality in 1985. Their approach to map conflation was to build a prototype using mathematical algorithms to perform geometric alignment between two vector datasets (i.e. census block boundary and road centreline map) (Saalfeld, 1988). This is a typical method for overlaying and integrating map layers. The key is to correctly identify matched feature pairs from both base maps. The Delaunay triangulation algorithm is then applied to partition spaces based on these matches and a rubber-sheeting method is used to align datasets in each triangle. The process is repeated until no further pairs of features can be identified on both datasets i.e. all possible correspondences are dealt with. Research followed to improve the efficiency of the method (C.-C. Chen, Knoblock, & Shahabi, 2006; C.-C. Chen et al., 2008; Dongcai, 2013; Freitas & Afonso, 2012; Sledge, Keller, Wenbo, & Davis, 2011).

The conventional map conflation processes are to make the base map/dataset with the highest geometric accuracy as the target map, then align all other maps/datasets to the target map including transforming attributes to the target map. Currently, different map layers can be quite easily aligned and overlaid using tools, such as the Google Map API or GIS (Geographic Information System) mapping software ESRI.

2.2.2 Geospatial Data Integration

As technology advances, ways to capture, store and present geospatial data have become more diverse. The need to integrate geospatial data with other information is also increasingly desired. Unlike traditional map conflation, once base maps for conflation are identified, much of the essential information required during the process is also known, such as, coordinate system, map scale, date created etc. Geospatial data is recorded in more formats than traditional maps and the data required to support decision-making is often now distributed across the Web. Matching methodologies based on geometric and topological matching criteria alone (Ruiz, Ariza, Ureña, & Blázquez, 2011) is no longer sufficient.

Tuchinda et al. (2008) demonstrated how to combine web sources of a list of Sushi restaurants with their health rating information. Szekely et al. (2011) proposed a workflow for merging online resources, i.e. associating telephone book information from the Yellow Pages or White Pages with buildings or structures shown in satellite images. McKenzie, Janowicz, and Adams (2013) focused on matching user-generated POIs from the Location-based Social Network Foursquare and the Yelp local directory service. These studies, about geospatial data integration, focused on separate stages of the integration process, such as data discovery (Parekh et al., 2004), data retrieval (Walter & Fritsch, 1999), data matching and linking (Sehgal et al., 2006; Wiegand & García, 2007). Even when the processes have been studied as a whole (Szekely et al., 2011), results only link the matched entities together and display all attribute values from each source (Ruiz et al., 2011). The value conflicts between different sources for the same attribute haven not been resolved, and a consequence, duplicate datasets still exist in dataset silos.

2.2.3 Geospatial Data Conflation

Contemporary geospatial data conflation processes need to deal with all the difficulties associated with data integration, in addition to merging or fusing multiple datasets into a single dataset. This involves decision-making, such as “which data is most accurate?” and “which data is more up-to-date?” However, the relevant information to support these kinds of decisions is usually vague. Hence, more geospatial data conflation research is required to combine overlapping geospatial data sources into a single source with richer attributes by reconciling conflicts and minimizing redundancy amongst source datasets, while still retaining the best attributes from each source.

Fusion can be further categorised. For example, Szekely et al. (2011) merged point data with the latitude/longitude representing buildings or structures with address information from Yellow or White Pages. The connection between these datasets is the vector data attributed with street information. It uses latitude/longitude information for each vertex so it can calculate distances to point data. Having street names means it can compare addresses extracted from Yellow or White Pages. Because each dataset contains only one aspect of the real-world object, the main challenge is finding matches. Once the nearest distance is identified and the name strings matched, the datasets can be fused. This method showcases the ‘attribute enrichment’ aspect of data conflation, which involves combining complementary properties.

The other part of the data conflation mission, to resolve conflicts and reduce duplicates, has not been well addressed. The work of Y. Zhang et al. (2013) reduced data redundancy wherever attribute values from both datasets were exactly matched, such as the exact name for a country/state or coordinates for a building. However, when the attribute value is different, the conflicts are not resolved. Instead they ‘union’ the attributes into a single list. Hence, there are multiple values for the same attribute in the resulting integrated list, such as two coordinate pairs representing the same building. The problem here is that two locations create confusion for a user when navigating to the building.

While matching and linking processes have been done semi-automatically or automatically using computer algorithms, the fusion process is difficult to automate with algorithms because it requires decision making, not only to look at the data itself, but also requires reference to other information or knowledge. It is hard for the computer algorithm to do this because it needs a domain expert's knowledge and intervention.

The fusion process requires holistic information, human logic and the sequencing of logic into a set of reasoning steps. Data sources that enable holistic reasoning include but are not limited to, reference data, business rules, metadata, provenance, topological relationships and/or even a domain expert's experience and knowledge stemming from years of work. This research endeavours to replicate the sequence of human logic through a series of automated reasoning steps and reference datasets to achieve a more holistic approach.

2. 3 Barriers Hindering Geospatial Data Conflation

2.3.1 Hierarchical Data Heterogeneity Barriers

Even though it has been studied since the early 1980s (Lynch & Saalfeld, 1985; Saalfeld, 1988), data integration and data conflation are still facing barriers that prevent satisfactory results to be achieved. One barrier is the heterogeneous nature of data. Data heterogeneity is classified into three categories: 1) syntactic heterogeneity 2) schematic heterogeneity and 3) semantic heterogeneity (Bishr, 1998).

- Syntactic heterogeneity is due to the use of different database systems (relational, object oriented etc.) and geometric representations (e.g. raster or vector representations).
- Schematic heterogeneity occurs when different data models are used to represent the same real-world objects.
- Semantic heterogeneity arises when different disciplines or user groups have different interpretations for the same real-world object. Naming heterogeneity is also a form of semantic heterogeneity, such as the same real-world object

having multiple different names or having the same name but referring to different real-world objects.

The heterogeneous nature of geospatial data makes it difficult to share and leads to data duplication problems because geospatial data are collected and processed differently to accommodate different organisations' views and format requirements. Various geospatial datasets describing the same real-world objects are typically identified and linked through their locations. Locations from each source won't be exactly the same, hence conflicts arise. In addition, the more data that is discovered and retrieved, the more conflicted values exist, leading to users finding it more difficult to decide which one is the best in order to remove duplicates.

2.3.2 Ontology-based Solution to Overcome Semantic Heterogeneity Barriers

A study by M. Lutz, Sprado, Klien, Schubert, and Christ (2009) shows that semantic heterogeneity can occur at the metadata level, schema level and data content level; each level blocks the discovery, retrieval, interpretation and integration of geographic information, respectively. M. Lutz et al. (2009) suggested ontologies as an appropriate mechanism to overcome these problems. Parekh et al. (2004) added semantics into metadata based on ontologies to improve geospatial interoperability efficiency and data discovery according to data content. Uitermark et al. (1999) developed a conceptual framework for ontology-based geographic data integration. Their work included generating domain ontologies for certain disciplines, and an application ontology for each geographic dataset. They also created abstraction rules to define the relationship between the concepts of domain ontologies and application ontologies.

Based on the idea that concepts from different application ontologies are semantically similar if they refer to the same concepts or related concepts in the domain ontology, then corresponding object instances can be defined as semantically matched. Frederico Fonseca, Egenhofer, Agouris, and Câmara (2002) proposed an ontology-driven geographic information system (ODGIS) in which ontologies are presented hierarchically with the Top-level Ontology at the highest level, Domain Ontology and Task Ontology at the middle level and Application Ontology at the bottom level. Their basic principle was to integrate what was possible and accept that some kinds of information will never be completely integrated due to their fundamentally different nature. They proposed that integration should always be done as the first point of intersection at the lowest level and then propagated upwards in the ontology tree.

2.3.3 Explore Semantic Web Technologies in Geospatial Domain

As Semantic Web and Linked Data concepts become increasingly popular, Semantic Web technologies such as RDF, SPARQL, OWL and SWRL etc. have been explored in the geospatial domain to improve the integration/conflation process. Berners-Lee, Hendler, and Lassila (2001) demonstrated how the WWW can be transformed into the next stage of the Semantic Web, the vision was quickly accepted by scholars in the geospatial domain. The Semantic Web envisions developing a document repository of the WWW into a network of well-structured meaningful, content-based web pages, so people and computers can understand and better work in cooperation.

Max J. Egenhofer (2002) proposed creating the Semantic Geospatial Web for meaningful use of spatial information by developing spatial ontologies to formally represent geospatial semantics. The notion is that geospatial information will be able to be retrieved in the context of users' queries since the semantics of geospatial information are incorporated into the Web of Data[10] in addition to the data itself.

Kuhn (2005) examined the benefits and challenges of geospatial semantics from the perspective of geospatial information semantic interoperability. This work highlighted that the solution of semantic interoperability goes beyond ontology construction and additionally requires reasoning.

Geospatial data integration studies have embraced advanced technologies developed for the Semantic Web. Parekh et al. (2004) added semantics to metadata through ontologies, which were generated using the Web Ontology Language (OWL)[11] so computers can understand the meaning of the information and perform operations

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[10] The Web of Data is acknowledged as an intermediate step on the way to the Semantic Web (Auer, Lehmann, & Hellmann, 2009).

[11] https://www.w3.org/OWL/

automatically. Using the data integration system Karma, Szekely et al. (2011) and Y. Zhang et al. (2013) have shown that geospatial datasets can be linked using ontologies to transform various source formats into the RDF format so data being integrated can be published and reused with rich semantic descriptions on the Web. Y. Zhang et al. (2013) also modelled data integration steps using an ontology, so that the processes can read RDF triples as input data and also return results as RDF triples. As a result, the system is able to offer some meaningful data matching and linking suggestions across heterogeneous datasets. Y. Zhang et al. (2016) took a similar approach to integrate geospatial datasets recorded in different languages (e.g. Chinese and English). Because features could be identified as the same through the Karma system, the matching and linking algorithm was able to be used as a translation tool.

A system named FAGI-gis further explores Semantic Web technologies in the geospatial data integration domain (Giannopoulos et al., 2015). The input to the tool is two separate geospatial datasets converted to the RDF format and stored in PostGIS databases. SPARQL endpoints are used to pull linkages between entities from both datasets and their associated attributes. The tool uses Virtuoso as its RDF triple repository to store outputs, and it supports GeoSPARQL[12] vocabularies so that geospatial features are presented as GeoSPARQL, Well-known text (WKT) serialization and Basic Geo. These integration systems typically use ontologies to model source datasets, and map data instances to the RDF format, based on the developed ontologies. Therefore, data instances can be provided with explicit meanings. Then, matching and integrating processes are normally executed through query languages.

2. 4 Using Semantic Web Rule Language to Automate Geospatial Data Conflation

While research has considered the SWRL rules in geospatial data integration, there is still much work to be done to enable the use of SWRL rules to infer new knowledge and derive implicit knowledge from explicit knowledge. Nonetheless, SWRL rules

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[12] https://www.ogc.org/standards/geosparql

have been used successfully in other geospatial data related applications and the demonstrated scope of these works can be applied to data conflation.

From the context of a future Geospatial Semantic Web application perspective, H. Chen, Fellah, and Bishr (2005) suggested SWRL rules can be used to execute low-level geospatial data processes guided by high-level computation logic. The processes do not require specific geospatial data to be coupled within the application implementation as in traditional methods. Thus, Geospatial Semantic Web applications have the potential to become more flexible and portable. Flexibility and portability are two characteristics desired for data integration processes using data available on the Geospatial Semantic Web.

In a Spatial Data Infrastructure (SDI), geospatial data while openly shared is heterogeneous and distributed in nature. Therefore, the discovery and retrieval of data to meet a user's requirements is a challenge. Klien (2007) stated that semantic interoperability is crucial for efficiently discovering and retrieving data because it enables data to be discovered by its contents rather than using the common simple keyword searching and string-matching methods. Ontologies are essential to semantic interoperability because they can explicitly describe domain concepts and terms so that the dataset contents can be semantically matched automatically. The work presents methods and tools for semantic annotation to map schema elements to domain ontology elements. It simplifies the similarity detection between the two elements for data suppliers. The intent is to promote ontologies as an acceptable practice in the geospatial community. SWRL rules in the research of Klien (2007) are used to semi-automate semantic annotation by specifying conditions for inferring data instances as certain concepts in the domain ontology. In this way, data instances are annotated with the explicit semantic annotation as defined in the domain ontology.

Michael Lutz and Kolas (2007) used SWRL rules to answer user's queries by making data easily discoverable in the context of an SDI. *Schema mapping rules* are defined to directly transform data instances under a source schema structure into data instances semantically described through a domain ontology. Thus, data instances can be stored in a knowledge-base and used for knowledge inferencing or reasoning.

Domain rules express the knowledge of domain experts and the logic required to answer a question that is formally constructed. By executing domain rules upon data instances in the Knowledgebase, answers can be inferred, and user queries are responded to. The same domain rules can be used to discover the data required to process the query.

Keßler, Raubal, and Wosniok (2009) take the research by Klien (2007) a step forward from simply modelling explicit knowledge using domain ontologies, and they have advanced the work by Michael Lutz and Kolas (2007) who simply combine information from data sources without incorporating any external information to generate SWRL rules. Keßler et al. (2009) use more complex SWRL rules to model a different user's choice of a surf-spot based on the combination of contextual information (e.g. wave height) and user's preferences (e.g. sandy bottom). They demonstrate how mathematical calculations are done using default SWRL Math Built-ins and also show how the same mechanism can be used to build custom built-ins to retrieve dynamic sensor information for the user-model rules instead of static hard-coded values for the ontology. Simple mathematical calculations, such as distance calculations, can be achieved using SWRL default Built-Ins (Keßler et al., 2009) as well as unique spatial relationship functions and spatial processing functions for geospatial data analysis can also be added through custom spatial Built-Ins for SWRL (Karmacharya, Cruz, Boochs, & Marzani, 2010). Therefore, spatial analysis can be integrated with domain knowledge (e.g. archaeology) to infer implicit domain knowledge and further enrich the domain knowledge base.

Karmacharya, Cruz, Boochs, and Marzani (2011) proposed using OGC standardised spatial relationships and function terminologies to build spatial Built-Ins for SWRL instead of application-specific terms (Karmacharya et al., 2010), so that Built-Ins can potentially become an OGC standard. Their research proposed the addition of a new spatial layer to the Semantic Web Technologies Stack. The vision is that spatial functions and analysis be integrated into Semantic Web technology development and vice versa; proven Semantic Web technologies can be utilised in geospatial analytics research to solve real world location-based problems. For example, Karmacharya et al. (2011) enriched the famous wine ontology (Natalya F Noy & McGuinness, 2001) with spatial features by running SWRL rules and spatial built-ins, therefore questions like, which wine is located in which region and sub-region or what are all the wineries in a specific region, can be answered.

In more recent research, the main focus of Devaraju, Kuhn, and Renschler (2014) was to formally model the relationship between sensor observations and geographical phenomena through ontologies. SWRL rules are used on top of ontologies to infer a specific type of geographical event (e.g. blizzards) using data from multiple meteorological stations. The SWRL rules embedded with the application-related information, domain knowledge and expertise, are used to model relationships, which was previously only the realm of domain experts.

Premalatha Varadharajulu, West, McMeekin, Moncrieff, and Arnold (2016) aimed to transform government policies, standards and business knowledge rules to automate the process for new road name approvals. Traditionally, there are grey areas within road naming policy that necessitate time consuming negotiations between developers and approvers, as to whether a proposed road name can be approved or not. For example, a policy defines that a road name cannot be used if it already exists within a 10km radius of the new road in city areas. Even though a developer is compliant with the policy e.g. the proposed name has not been used in the vicinity, the proposed name may still be rejected because of an additional rule that says a suffix type as ‘place’ or ‘close’ cannot be used on the road as it greater than a specific length (200m). Sometimes, the cause of rejection is not in written policy but a common practice adopted by subject matter experts. To enable automatic evaluation and approval of new road names, they extracted domain experts’ knowledge and experience in dealing with potential conflicts regarding the proposed new road name as well as standard policies, and created a standard set of SWRL rules based on them so that land developers and surveyors can use the online service to check whether their proposed names conform to naming guidelines and can thus be used in the new land development without consulting authorised approvers.

Each rule, in the above-mentioned systems, captures one aspect of the knowledge-base, they are either distinct from each other (Devaraju et al., 2014) or related loosely (Premalatha Varadharajulu et al., 2016). In this research, SWRL rules are used to model human logic in the geospatial data conflation process where decisions are made step by step, and for each step the decisions made will have an influence on the subsequent step in the process and the final conflated result. Essentially, the set of SWRL rules in this research are tightly coupled with each other and are based on forward chaining inferences to realise the final conflation decision.

In conclusion, the geospatial data conflation process is time consuming as it is difficult to determine which data is the most appropriate in terms of data accuracy, currency and completeness. Human experts must examine the accuracy and quality characteristics of each feature within each data source and explore various information and knowledge to facilitate their decision-making in order to deliver an output dataset that meets application needs.

Human experts normally contribute information and knowledge to perform data conflation processes, ranging from application-specific knowledge, to domain related policies, industry standards or business rules, to common sense or generic geography theories/principles. The proposed SWRL rules-based methodology in this research allows this knowledge to be extracted and expressed in a declarative way and used automatically to conduct reasoning to compare, match and link duplicate data instances to identify a single real-world representation according to human logic. The methodology is intrinsic to resolving duplication problems and reducing the need for human interventions in the conflation process, thus achieving an automated geospatial data conflation process.

2. 5 Building Automatic Geospatial Data Conflation System on Top of Common Data Structure – the Resource Description Framework

SWRL rules play a key role in the desired automation of the geospatial data conflation system. From a technical point of view, there are necessary prerequisites for the SWRL rules to run upon the geospatial data. As can be seen from the layer structured Semantic Web Technologies Stack (Figure 1.2) (Berners-Lee, 2000), rules sit at the highest level of the architecture. SWRL rules rely on data representation in the form of RDF, which serves as a foundation for building the Semantic Web (Semantics, 2020). RDF is a W3C standardised data interchange format (Consortium, 2014) intended for encoding any resource on the Web, including the representation of geospatial RDF data. The simplest yet flexible data model of RDF, in the form of

<subject, predicate, object> triple, is regarded as more beneficial for geospatial data than other data domains, as the geospatial data modelling is recognised as very complex and it leads to schema integration being a very difficult task (Park, 2001; Volz, 2005). According to Kuhn, Kauppinen, and Janowicz (2014), such complexity can be hidden behind geospatial data custodial organisations when data is represented in a single common format, i.e. the RDF. The authors believe the well-known hierarchical data heterogeneous issues (i.e. syntactic, schematic and semantic heterogeneities) that interfere with effective geospatial interoperability can be simplified to the representation of geospatial RDF where problem solving can focus on how to produce and maintain vocabulary specifications as well as sharing vocabularies.

However, some early utilizations of Semantic Web technologies are more focused on the OWL and SWRL rather than RDF (Klien, 2007; Michael Lutz & Kolas, 2007; C. Zhang, Li, & Zhao, 2007). At the time, a series of OGC standards, such as Geographic Markup Language (GML), Catalogue Service for the Web (CSW) and Web Feature Service (WFS), were greatly improving the geospatial data interoperability at the syntactic level within the SDI environment. Typically, geospatial features were encoded in the GML format (Cox, Daisey, Lake, Portele, & Whiteside, 2002), searched by users through CSW (OpenGeospatialConsortium, 2007) and retrieved by WFS services (OpenGeospatialConsortium, 2010). The idea was for SDI data providers to add semantic annotations to their geospatial data (Klien, 2007), so that both data content and schema semantics could be explicitly expressed via catalogue services. In this way, when SDI users want to answer certain questions that require combining multiple geospatial datasets, they are able to use rules to discover the most fit-for-purpose geospatial datasets (Michael Lutz & Kolas, 2007) other than just using simple queries based on keyword matching, i.e. string match between search terms and text-based metadata items through CSW.

Therefore, the primary form for providing geospatial data in SDIs is GML (Klien, 2007) other than RDF, and some data providers are using WFS to share data while the underlying data is in a legacy GIS format (C. Zhang et al., 2007). The implementations of Semantic Web Technologies in these research programmes provide semantic interoperability in the context of improving accuracy for data discovery and data retrieval in a way that is more relevant to users' needs. However, meaningful data conflation is far from being achieved today as schema interoperability and semantic interoperability, at the data instance level, cannot be resolved using the GML format.

Presenting geospatial data as RDF data (Auer, Lehmann, et al., 2009; Becker & Bizer, 2009; Goodwin, Dolbear, & Hart, 2008) is increasing due to the popularity of Linked Data activities. Linked Data is a general term for referencing RDF data that is published on the Web according to a set of principles proposed by Berners-Lee (2006), which are: 1) use URIs (Unique Resource Identifier) as names for things; 2) use HTTP URIs so that people can look up those names; 3) when someone looks up a URI, provide useful information, using the standards (RDF, SPARQL); and 4) include links to other URIs so that they can discover more things.

Linked Data activities are regarded as best practices for Semantic Web (Bizer, Heath, & Berners-Lee, 2011). Examples are DBpedia[13], GeoNames[14] and EuroStat[15]. DBpedia is one of the central interlinking hubs as datasets from other sources can link to it, as well as link to each other through DBpedia via *owl:sameAs*[16] property. The owl:*sameAs* property is used to establish links between individuals indicating that two individuals have the same 'identity', i.e. two URI references actually refer to a same thing. The LinkedGeoData (Auer, Lehmann, et al., 2009) project follows the Linked Data paradigm intended to enrich the Web of Data with a spatial dimension, i.e. transforming OpenStreetMap (OSM) spatial data into RDF data and publishing the data by adhering to Linked Data design principles. Furthermore, the linkage between LinkedGeoData data and the existing DBpedia data is built up by a created set of owl:*sameAs* pairs. Consequently, the LinkedGeoData project data can also link

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[13] DBpedia is a crowd-sourced community effort to extract content from the information created in various Wikipedia projects. https://wiki.dbpedia.org/

[14] GeoNames is integrating geographical data such as names of places in various languages, elevations, population and others from various sources. https://www.geonames.org/

[15] EuroStat is the statistical office of the European Union that provides high quality statistics data for Europe. A subset of the EuroStat data that defines a hierarchical system of economic territories is provided as Linked Data. https://ec.europa.eu/eurostat/web/nuts/linked-open-data

[16] https://www.w3.org/TR/owl-ref/#sameAs-def

to other datasets where *owl:sameAs* linkages are already identified with DBpedia, e.g. GeoNames.

On the other hand, the administrative geography RDF published by Ordnance Survey (Goodwin et al., 2008) is a typical representation of an authoritative data source where data accuracy is guaranteed compare to unofficial data sources (e.g. LinkedGeoData). A decade later, another linked dataset Geographic Name Information System – Linked Data (GNIS-LD) (Regalia, Janowicz, Mai, Varanka, & Usery, 2018) released by the collaboration of US government agencies is claimed to be a milestone for the linked geodata community as it is one of the few authoritative geographic datasets that are triplified and published as Linked Data. The GNIS-LD is the most comprehensive and latest version of US authoritative names of places. It is regarded as more advantageous than GeoNames and LinkedGeoData in terms of data within the US boundary. Because both GeoNames and LinkedGeoData datasets were more or less originally sourced their US part of data from the Geographic Name Information System (GNIS) but the most current version of GNIS has not been updated on them. Furthermore, both GeoNames and LinkedGeoData allow community contributions, which is good for the broader community collaboration but on the other hand its data accuracy and authoritativeness cannot be guaranteed. Nevertheless, the authors regard this authoritative dataset as a complement to the existing ones instead of replacing them due to their update intervals, coverage and accuracy etc. that are different. Together, the datasets provide data users with choices fit to their needs. These place names Linked Datasets are important for linking data across domains on the Web of Data.

There is a lot of data on the Web that can be geo-enabled when associated with geographical coordinates, such data are called geo-tag contents. Location information is one of the properties that are related to an entity in a dataset and it enables the entity to be shown on a map (Becker & Bizer, 2009). However, if data entities from different sources located in the same proximity or even have the same location, their relationship can’t be asserted because the semantic linkage between the locations is not explicit. Therefore, Becker and Bizer (2009) argued that by presenting geospatial data as RDF and publishing them as Linked Data make them the first-class citizens of the Semantic Web. This allows locations to be treated as web resources just like any other types of resources and are assigned with unique URIs. In addition to simple geographical coordinates, they also contain links to other locations and semantic relationship types that can be explicitly expressed as well, such as a point presenting a restaurant is within an administrative boundary of a city. Furthermore, linking outside the location resources to broader resources on the Semantic Web is applicable which enables rich information about a location to be discovered and leading to better understanding of the location's context. Such advantages are also demonstrated in the research by de León et al. (2010) where datasets (including hydrographic features, administrative boundaries and statistical data) are openly available from Spanish government institutions. By transforming datasets into RDF form, administrative units are aligned with statistical information through *owl:sameAs* relationship, so the geometric information is enriched with statistics aspects, such as population, unemployment and industry etc. The administrative points are also linked to hydrographic features, allowing the analysis of their existing relationships to the interested coastal areas and their social-economic aspects.

Steering back to the SDI perspective, it is by far the most predominant way to disseminate standardised geospatial data in hierarchical levels (national, regional and globally). However, its shortcomings are also prominent and widely acknowledged within the community as finding, accessing and using appropriate data disseminated through SDIs, particularly for non-expert users, are still difficult tasks (Vilches-Blázquez & Saavedra, 2019). Geospatial data maintained and disseminated through SDIs on the Web is isolated from other information domains, and cannot achieve its meaningful integration with other data (Huang, Raza, Mirzov, & Harrie, 2019; Schade, Granell, & Diaz, 2010; Yue, Guo, Zhang, Jiang, & Zhai, 2016). Therefore, it is no surprise that there are many efforts in the SDI community to leverage Linked Data principles to overcome its shortages, particularly given the success of Linked Open Data due to its simple representation format of data – RDF and its widespread adoption (Abbas & Ojo, 2013).

There are two common scenarios presented by Schade et al. (2010) that show how Linked Data principles can be used in augmenting SDIs.

- The first scenario is based on the existing SDI standard structures, where data resources stay unchanged but links are added at the service levels, which are embedded within their metadata descriptions. That means if multiple SDI services are all related to the same resource, appropriate linkages can be established between them. This method easily provides interlinkage capabilities among SDI resources; however it is not able to go beyond the SDI technical infrastructure to connect with broader data such as Linked Data on the Web.

- The second scenario is considered as real Linked Data augmentation where data resources in SDIs are actually provided as RDF outside the SDI infrastructure. This is an extension on the first scenario where links embedded within metadata are defined in RDF-S giving them well defined semantics (e.g. link type definition). The basic mapping between GML and RDF are specified as *xlink:href=rdf:resource* and *gml:identifier=rdf:about,* so that GML encoded geospatial data can be provided in RDF.

Having both options, means that data providers and data consumers can negotiate content at both service level and feature level, i.e. data providers can offer their data and metadata using common SDI standards or encode them as Liked Data using RDF so that data consumers have options for choosing which links to follow and retrieve their desired encoded format data (i.e. in GML or RDF). Together, the two methods enable SDI data holdings to be provided globally leading to in-depth integration potential for Linked Data and SDI being achievable.

Schade et al. (2010) were clearly in favour of the RDF based Linked Data approach as it not only enables linking between SDIs but also enables linkages to the broader world beyond SDIs. But they also point out that at the end there is no official policy or technical guidelines for implementing Linked Data principles in SDIs according to their observations. Whether geospatial data is provided in RDF and adding linking capabilities is optional.

The lack of policy, standards and guidelines for implementing Linked Data SDIs are also acknowledged by Abbas and Ojo (2013). Their study developed a Reference Architecture for governments to refer to when developing their Linked SDIs. Five classic dimensions were identified in the study based on existing SDIs, i.e. Data, Network, People, Standards and Policy. Regarding the Data Dimension, it is giving an explicit technical guideline for the Linked SDI that data under three categories should be presented in RDF format and managed based on Linked Data principles. These data are 1) foundation datasets such as geodetic controls and geo names datasets that cover geospatial aspect of SDI, and these places and locations should be given a URI with links pointing to other related places; 2) framework datasets such as land cover and administrative boundaries that cover particular thematic information at the national level; and 3) application-specific datasets such as LinkedGeoData and DBpedia etc.

The provision of these geospatial datasets as RDF is demonstrated by van den Brink, Janssen, Quak, and Stoter (2014). The authors pointed out that a wealth of geospatial data presented and exchanged in standard GML format based on predefined structuring of semantics within domains, can be created thanks to the standardised effort in traditional SDIs. That is, a lot of work has been done to transform local sources stored in various formats to the GML structured format. Therefore, Linked SDIs can simply reuse these existing GML resources by standardizing the processes of GML to RDF transformation. The feasibility of such geospatial RDF data transformation is also backed up by Schade and Cox (2010) where the authors argue that the principles of GML and RDF are isomorphic. Although later versions of GML standard have been developed in favour of XML Schemas, the first version of GML had explicit RDF/XML implementation binding and the later versions are strongly influenced by the RDF structure.

Implementing Linked Data within the SDI environment has continued to gain traction over the last five years. Specific applications such as web-based spatial data fusion, uses Linked Data principles to formalise and manage feature relations as part of the fusion process (Wiemann & Bernard, 2016). Also, from a web-based service perspective, Yue et al. (2016) explore the integration of Linked Data practice into Web Geoprocessing workflows; while Vilches-Blázquez and Saavedra (2019) specifically focus on connecting WFS to Linked Data.

Linked Data is seen as a key factor towards the development of the next generation SDI, i.e. Spatial Knowledge Infrastructure (SKI), which can automatically create, share, curate, deliver and use data or information, as well as knowledge creation to support decision making (L. M. Arnold, McMeekin, Iványová, & Armstrong, 2019; Duckham, Arnold, Armstrong, McMeekin, & Mottolini, 2017). The core of the Linked Data approach is to assign URIs to data resources and present the data with the universal graph data model RDF.

In addition, the continuing efforts of developing geospatial RDF conversion tools (Hamdi, Abadie, Bucher, & Feliachi, 2015; Kyzirakos et al., 2018; Kyzirakos, Vlachopoulos, Savva, Manegold, & Koubarakis, 2014; Patroumpas, Alexakis, Giannopoulos, & Athanasiou, 2014; Patroumpas, Skoutas, Mandilaras, Giannopoulos, & Athanasiou, 2019; Vilches-Blázquez & Saavedra, 2019), the studies and evaluation works for the geospatial RDF triple stores (Athanasiou, Bezati, Giannopoulos, Patroumpas, & Skoutas, 2013; Garbis, Kyzirakos, & Koubarakis, 2013; Huang et al., 2019; Ioannidis, Garbis, Kyzirakos, Bereta, & Koubarakis, 2019; Raza, 2019) are all demonstrating the need for presenting geospatial data in RDF format for use by geospatial communities. Therefore, in this research, the idea of transforming multiple sources of geospatial data into the common data format - RDF – is justified as it not only fulfils the technical requirements of the geospatial data conflation system, it is also compliant with the current direction of geospatial community research.

2. 6 Presenting Geospatial Data Semantics using the Web Ontology Language

In addition to RDF (the foundation for the desired AGDC system) and SWRL rules (used for automatic reasoning steps), OWL is another core technology to be used in the proposed AGDC system.

In the original Semantic Web Technology Stack (Berners-Lee, 2000), Ontology vocabulary is the level immediately above RDF. An Ontology vocabulary contains a set of terms and the interrelationships between these terms in a domain of interest and can be shared by the domain communities. Ontologies specify the explicit knowledge information for RDF triples, i.e. semantics. Instead of just presenting information for humans to read and understand, formally defined ontologies enable applications to process Linked Data content on the Web automatically. OWL is designed for such a purpose i.e. to meet web ontology language needs. OWL goes beyond the ability of basic semantics, such as RDF Schema, and provides more vocabularies to express machine readable meanings and semantics for web content. OWL[17] has been a W3C standard since 2004 and is currently at second generation (OWL2)[18] with revisions and extensions of its original version. OWL/OWL2 not only provide great expressiveness for developing ontologies in different domains, but also serve as a common platform for sharing, reusing and redeveloping existing vocabularies due to its W3C standard based representation (Budak Arpinar et al., 2006).

Early adoptions of OWL in the geospatial domain are examples like Budak Arpinar et al. (2006), Kolas, Dean, and Hebeler (2006), Parekh et al. (2004) and C. Zhang et al. (2007). Aimed at developing an ontology-based semantic metadata management system, Parekh et al. (2004) addressed the geospatial data discovery problem across the Web. They showed how ontology-based metadata, which combing domain ontologies and data model ontology that defines the identification, spatial extent, temporal extent, data content and data distribution of dataset etc., enables data to be discovered based on content instead of key-word match. The utilization of OWL adds more semantics to the ontologies because of its expressive nature and facilitates machine interoperability.

In order to realise efficient integration and sharing of multiple types of geospatial data in the distributed Web environment, Budak Arpinar et al. (2006) proposed a Geospatial Semantic Analytics (GSA) framework for comprehensive and reliable information analysis. Their work goes beyond 'thematic' only information analysis to include the dimensions of 'space' and 'time' from various information sources. The foundation of the GSA is the development of spatiotemporal thematic ontologies, which can explicitly define space relations (e.g. *near* or *surrounded by*) as well as enable spatiotemporal thematic proximity measurements. The GSA ontologies were created using a commercial product named Semagix Freedom in

[17] https://www.w3.org/TR/owl-features/

[18] https://www.w3.org/TR/2012/REC-owl2-overview-20121211/

which users can define classes and their relationships, and later exported in either OWL or RDF syntax through Freedom's API. This approach to implementation was to ensure ontologies and metadata are formally presented with the emerging Semantic Web ontology representation standard of OWL.

Aimed at legacy geospatial data sharing and cost effective integration across the WWW, C. Zhang et al. (2007) proposed a framework based on Geospatial Semantic Web technologies which includes ontology, OGC web services and the Service-Oriented Architecture (SOA) to reduce duplication and enable sharing and reusing. The utilization of ontology in each SOA architecture component is what differentiates the SOA from the traditional web services. There are four components contained in the proposed framework. The Service Provider and Service Client are the two major components, which supply geospatial data and consume the data. Sitting in between these two components is the Service Broker that provides a registry for the available services. The last component is the Ontology Server which ensures provider ontologies and client ontologies are semantically interoperable. The prerequisites of semantic interoperability include maintaining local ontologies in both Service Provider and Service Client sides, so they are able to communicate with each other. Then the Ontology Server is able to generate mappings between the local ontologies and maintain a taxonomy of geospatial terminologies. The Ontology Server is used by Service Brokers to build mappings between traditional OGC catalogue services and ontology-based catalogue services.

The web-based ontologies created in the SOA framework are OWL ontologies. OWL-S (Semantic Markup for Web Services)[19] which is an upper-ontology based on OWL that is used for semantically enriched web services. It provides a characteristic description for Web Feature Services (WFS) and Web Map Services (WMS). The use of OWL-S enables the underlying legacy GIS and application access to be free from being tied to a particular system or software and can be easily interacted with each other.

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[19] https://www.w3.org/Submission/OWL-S/

Similar to the research done by C. Zhang et al. (2007) which aims to further advance the current geospatial web (improved by SDI and OGC web service technologies) with Semantic Web technologies; by developing an architecture of ontologies using OWL, Kolas et al. (2006) added a semantic layer to the existing geospatial web (advanced by standard geospatial data formats and web services, specifically GML and WFS) to augment and enrich with rich semantics. Semantics is the inherited knowledge of application solutions (i.e. the way to solve a specific problem) objectively existing irrelevant to the data but complement to the data. The semantics are not contained in an application but in the form of OWL ontologies, therefore, any application can easily manipulate, query or build on top of the OWL ontologies. These ontologies serve as the foundation for presenting geospatial information uniformly while also extending the data linkage ability to other knowledge outside of the geospatial realm because of the greater expressiveness of OWL.

The great expressiveness of OWL is also appreciated in the work by Durbha, King, Shah, and Younan (2009), which intends to resolve semantic heterogeneity issues and conflicts regarding Earth Observation (EO) data obtained for different thematic purposes, such as land cover, soils and wetlands etc. One unique character of EO data is that data analysis results are normally presented as a set of classifications relevant to a specific thematic classification system. Therefore, the conflicts between classification schema domains need to be resolved before effective data integration can happen. The proposed solution in this study is to generate local ontologies based on different classification schemes and map them to a single shared ontology for the integration. Using OWL to develop ontologies allows classes to be defined in multiple and flexible ways, for example, define classes using property restrictions (a.k.a properties that meet certain values). OWL enables classes to be expressed in various conditions, such as whether it is a *primitive class* that is only defined by necessary conditions or a *defined class* that has to meet both necessary and sufficient conditions. Such OWL ontologies can be read by a reasoner that can automatically infer new knowledge if it has not been explicitly given. For example, if an entity is known to belong to a certain class, then the reasoner can infer it has all the properties belonging to the class. However, it cannot be concluded that an entity has a set of necessary properties belonging to a class unless it also has the sufficient properties. Running a reasoner frequently during the OWL ontologies generation process enables additional characteristics to be found and the hierarchy inferred for the classes as well as ensuring the whole ontologies' consistency.

OWL ontologies allow DL reasoners to draw inference on the semantics involved in establishing class hierarchies or/and class/individual designations. Such reasoning happens at the conceptual level. A step further is to combine the use of OWL ontologies and SWRL rules where more complex conditions can be expressed through SWRL rules so that knowledge inferencing can happen at the data instance level. In the research work of Klien (2007), which demonstrates a SWRL rule-based method to establish mappings between geodata schema and domain ontology (semantic annotation), the first step of their process is to transform the application schema into OWL syntax ontology so it is encoded as the same language structure as the domain ontology. Such a transform is a solely syntactic structure change with no additional information being added into the meaning of concepts. The Domain ontology specifies a taxonomy in a particular domain where concepts and relationships are defined in a broader spectrum, while the application schema just reflects one possible representation of a generic concept. A direct mapping may not be appropriate even if the concept names in both application schema and domain ontology are the same. Therefore, in the second step, SWRL rules established are used to check against data instances, where only instances that meet a series of conditions are defined in the SWRL rules during the spatial analysis and are qualified as a feature of a certain concept. The combination of OWL ontologies and SWRL rules approach is applicable exclusively at the level of spatial data instances and provides a novel ontology mapping method that has not been utilised in the geospatial data domain.

Similarly, other studies also demonstrate the exploration of OWL ontologies and SWRL rules in combination to resolve geospatial data related issues, such as the discovery of fit-for-purpose datasets in SDIs and subsequently answering user queries based on the discovered data (Michael Lutz & Kolas, 2007), and to automatically discover and retrieve geospatial data (Wiegand & García, 2007), and where the conditions of geospatial data retrieval involve numeric calculations (Keßler et al., 2009). The advantage of OWL ontologies is that domain-specific knowledge can be presented with more flexibility because of the expressive nature of

OWL. In this way, ontologies can be formalised as machine-readable so reasoners can perform subsumption reasoning where implicit taxonomic relationships between classes or between a class and individuals can be explicitly inferred. In addition, SWRL can help overcome OWL ontology limitations by adding more declarative expressivity. OWL ontologies limitations have been identified as the limit assertion ability between two individuals' relationship (Michael Lutz & Kolas, 2007), inability to express complex concept relationships that require using variables (Klien, 2007), and the lack of mathematical calculation capabilities (Keßler et al., 2009) etc.,

2. 7 Literature Review Findings

The perception from this literature review is that the importance of the OWL ontology, in enabling explicit communication among geospatial datasets, is being increasingly used within the geospatial sector. The use of OWL ontology at the metadata level enables heterogeneous geospatial data distributed across the Web to be automatically discovered and evaluated where it fulfils application requirements because it is based on content rather than key-word search. The use of OWL ontology at the schemata level enables retrieved datasets to explicitly communicate class/subclass and class/individual relationships between each other, so the matching and linking at feature classes level can occur automatically. However, what is still missing is the explicit communication and automatic reasoning at the data instance level. Therefore, human intervention is still heavily required to reduce data duplication during data conflation process.

The proposed method in this research is to generate an OWL ontology based on a fit for multiple purposes output data model which might be the best data model among the source datasets or a commonly accepted standard data model. Such an ontology acts as a domain ontology and is then expanded to accommodate various geospatial source datasets. Then the generated OWL ontology will be used in the process of transforming source geospatial datasets into RDF triples. Therefore, the semantics of each RDF triple will be explicitly specified based on the OWL ontology. In this way, each geospatial feature in the source datasets will be presented by multiple RDF triples, some triples containing schemata information for inferring class/subclass or/and class/individual relations, and some triples containing attribute information where attribute values are explicitly specified. These semantic rich RDF triples are the basis for the proposed logic modelling SWRL rules set to reasoning on and automatically decide what data values to keep in the conflated result.

2. 8 Summary

This chapter provides a review of geospatial data integration and conflation studies in literature. The below diagram Figure 2.1 summarises the findings in the literature reviews.

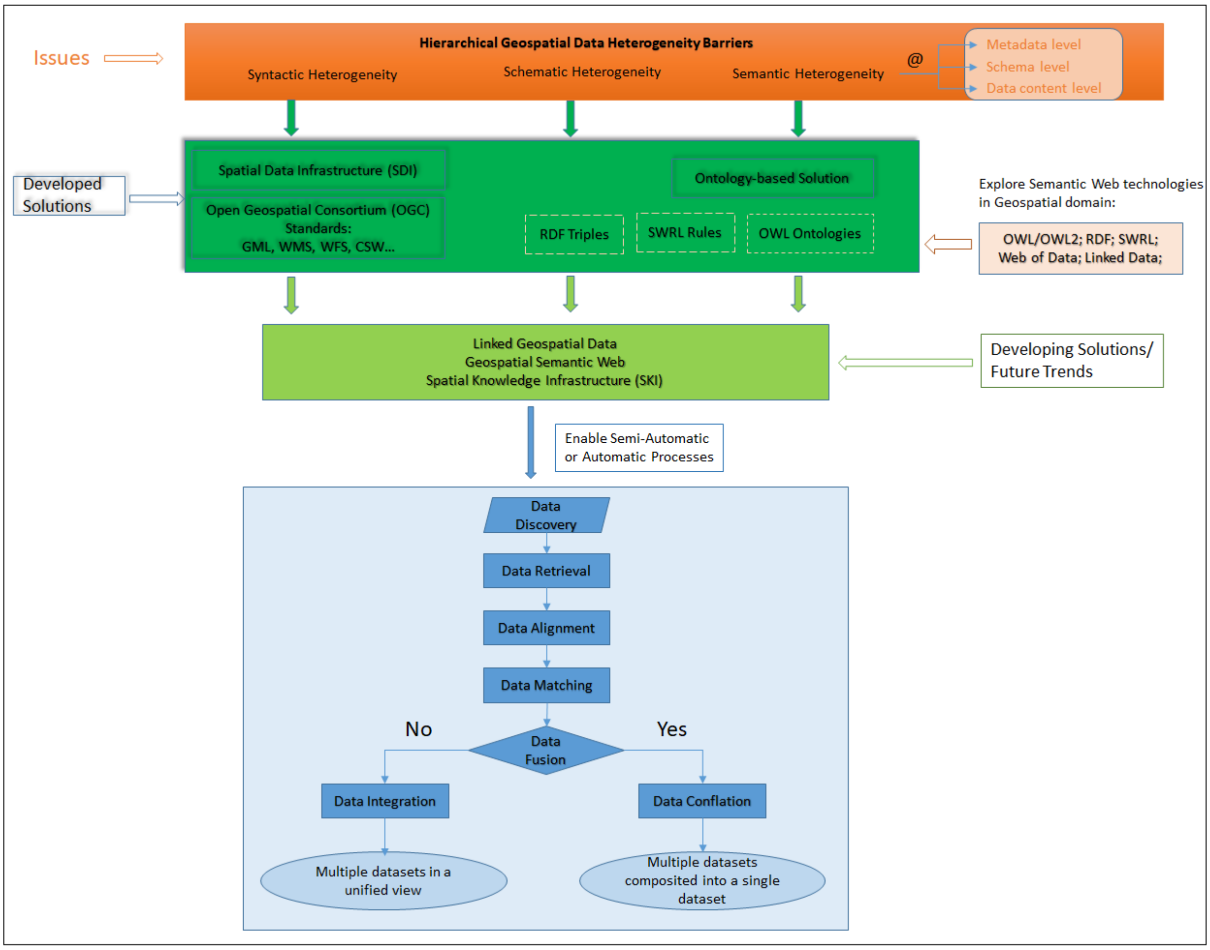

Figure 2.1 Literature Reivew Summary

Even though data integration and conflation has been studied over three decades, ways to achieve automatic or semi-automatic geospatial data conflation approaches are still far from satisfactory. Major barriers are the hierarchical data heterogeneities that occur at the syntactic, schematic and semantic levels of geospatial data. They are identified as Issues in the Figure 2.1.

Progress has been made through standardised efforts that greatly improve syntactic interoperability between geospatial data, such as policies and standards within SDIs and OGC standards for web services (e.g. Web Feature Service and Web Map Service etc.). And Ontology-based solutions intend to tackle semantic interoperability issues. However, schematic and semantic heterogeneous barriers still heavily hinder automatic conflation. Several studies have demonstrated that the utilization of the Semantic Web technologies in the geospatial data domain can successfully overcome some of the barriers and facilitate the management and manipulation of geospatial data. Therefore, the increasingly popular and matured Semantic Web technologies are explored in the geospatial domain. As a result, Linked Geospatial Data, Geospatial Semantic Web and Spatial Knowledge Infrastructure are becoming developing solutions and future trends. This research explores Semanitc Web technologies to enable automated geospatial data integration and conflation. This aspect is explained further in Chapter 6, which demonstrates a combination of RDF, OWL ontologies and SWRL rules to build the AGDC system developed in this research. This work also builds on other research that has shown that RDF triples can be used to overcome syntactic and schematic barriers among heterogeneous geospatial datasets; while OWL ontology can be used to facilitate RDF triples to minimise semantic barriers.

Both the utilization of RDF triples and OWL ontologies can be used to express geospatial data enabling conflation SWRL rules to work on top of geospatial RDF triples, i.e. understand the triples' explicit semantics and perform reasoning based on them. In the following chapters, each of the technologies will be studied in detail to demonstrate why the combination of these individual technologies is necessary in the AGDC system and how they interrelate to automate data conflation.

3 COMMON DATA STRUCTURE

This chapter aims to explore the Resource Description Framework (RDF) [20], the data model of the Web of Data whose ultimate goal is the Semantic Web (Auer, Lehmann, et al., 2009; Jain, Hitzler, Yeh, Verma, & Sheth, 2010), as a novel way to resolve data heterogeneity issues at the syntactic, schematic as well as semantic level of geospatial data. A review of the current methods is undertaken towards transforming legacy geospatial data into the RDF format and the triple stores available to effectively manage and query RDF formatted geospatial data.

3. 1 RDF Essentials

RDF is a framework for representing information about resources on the Web. Resources can be anything: a person, a city, a movie, any physical object or abstract concept. It is a W3C standard (Consortium, 2014), which was initially intended to provide a standard way to provide descriptions about resources on the Web (i.e. metadata). It has now become the standard data interchange format for the Semantic Web, capable of presenting any data. Data represented in RDF format is not only understood by people but is also machine-readable and can therefore be processed automatically by applications.

The data model of RDF is very simple. It is a set of triples containing a subject, a predicate and an object. It can be graphically presented as two nodes connected by a directed arc, which is called an RDF graph, see Figure 3.1.

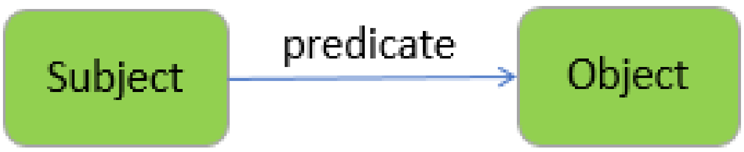

Figure 3.1 RDF data model in the form of RDF graph

As demonstrated in Figure 3.2, RDF expresses a relationship between two resources, such as two persons named Dan and Bruce. Where Dan is Bruce's son, the RDF

[20] https://www.w3.org/RDF/

statement reads Dan *isSonOf* Bruce since it corresponds to an RDF triple where Dan is the subject, Bruce is the object and their relationship is indicated by the predicate *isSonOf*.

An important part of RDF's power is that a resource can be referenced in multiple triples, i.e. it can be the subject in one triple and the object of another facilitating the connection of multiple triples. For example, in Figure 3.2. Dan can also be connected with other persons in his family. This simple data model and linking functionality of RDF, make it possible to present data of any kind and relate any disparate data to each other.

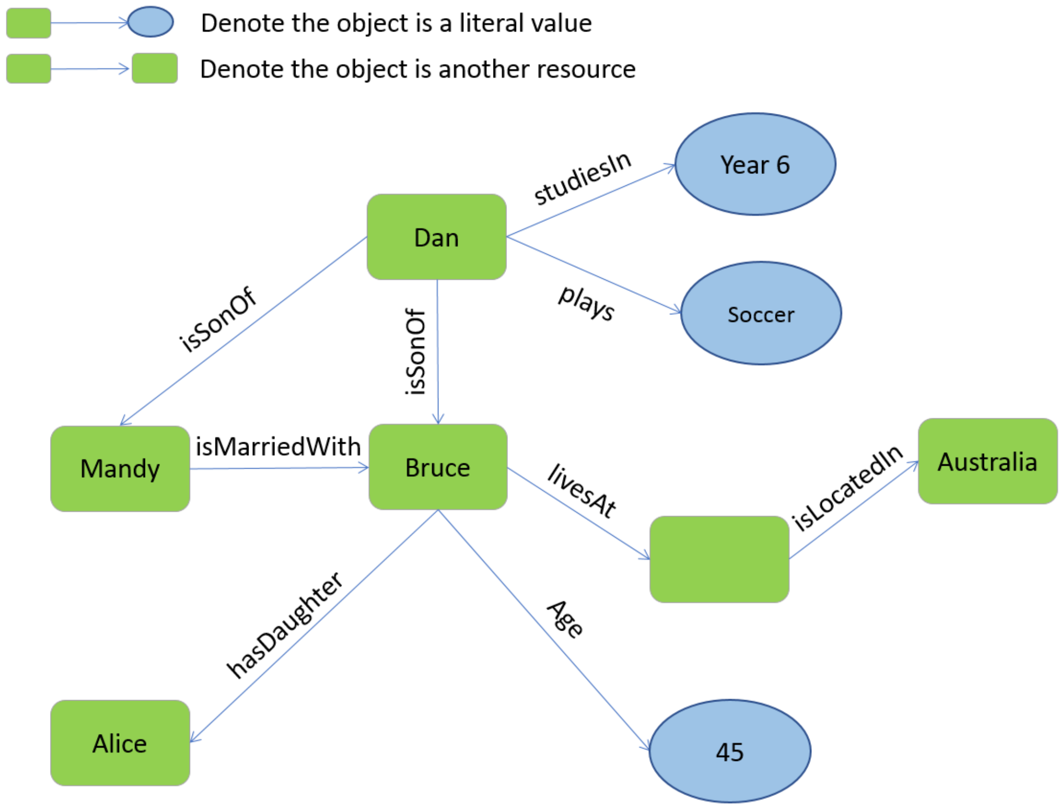

Figure 3.2 Multi-linking RDF triples

In the RDF graph, nodes can have three different kinds of presentations. The first kind of node is IRI (International Resource Identifier) that uses commonly used URLs (Uniform Resource Locators) as addresses to locate resources on the Web. When a resource is given an IRI, it means a unique global identification is assigned to the resource but without implying its location or how to access it. IRIs can be used in all three positions of a triple and different users can re-use an IRI to identify the same resource. When the node in an RDF triple is not an IRI but a basic value, such as values inside the blue oval shape in Figure 3.2, it is a Literal. Literals normally only appear in the object position in an RDF triple and are associated with a datatype, which then provides the correct interpretation of the literal. For example, a number may be associated with integer type or float type and a string may be associated with a language tag. The last type of node is a blank node where resources can be referred to but without giving their values or without explicitly giving them IRIs. Such a blank node example is the blank node in Figure 3.2, where it shows Bruce lives somewhere and that place is inside Australia but not knowing where he lives exactly. Blank nodes can be used in either the subject or object position in an RDF triple.

One thing that needs to be pointed out, is that the RDF data model only provides a standard way to make descriptions about resources, the data model itself does not contain any semantics. The use of RDF in practice is typically needed to be used in combination with vocabularies or ontologies in order to entail semantic information about resources (Manola, Miller, & McBride, 2014). Such vocabulary or ontology can be generated using languages such as RDF Schema[21], which defines a simple set of classes to specify the category of a resource (for example, *rdfs:Datatype* denote the class of RDF datatype) and a collection of property types to identify the relationship type between two resources (for example, *rdfs:subClassOf* denotes the subject is a subclass of a class).

When more comprehensive semantic modelling of RDF data is required, the W3C standard language OWL[22] can be used to provide more rich and complex representation capabilities about resources, group of resources and relations between resources. Once the vocabularies or ontologies are designed and agreed widely across data providers and data users, the semantics of RDF triples are explicitly defined and understood by various parties making the meaningful merge of disparate data achievable.

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[21] https://www.w3.org/TR/rdf-schema/#ch_summary

[22] https://www.w3.org/OWL/

Another benefit of semantic enriched RDFs is that it enables logical inferences (Hayes & Patel-Schneider, 2014). From a human perspective, when people are given some information known to be true, they can infer new information from it. This kind of behaviour is called reasoning. For example, from Figure 3.2, we know that Mandy and Bruce are married, and Bruce has a daughter called Alice. Using common sense, we can infer that Alice is also Mandy's daughter. Such reasoning can be done automatically by applications using an inferencing system called "reasoner"[23]; taking explicit triples *Mandy isMarriedWith Bruce* and *Bruce hasDaughter Alice* as input and deducing an additional triple as *Alice isDaughterOf Mandy*. However, these kind of reasoning behaviours need to be specified using rule languages, such as SWRL before they can be run in a "reasoner".

In summary, RDF is a basic building block to the Semantic Web. Its simplicity and flexibility make it possible to represent any kind of data. The ability of embedding explicit semantics in the triples, makes it possible for data to be used in more complicated scenarios, such as inferring new information, linking different datasets and building complex relationships etc. In the next section, a comprehensive review will be conducted to justify why RDF is the data interchange format to be used in the geospatial data conflation processes to overcome the data heterogeneity issues.

3. 2 A Common Data Interchange Format to Overcome Data Heterogeneity Barriers

As already pointed out, a well-recognised barrier to spatial data conflation is data heterogeneity. Data heterogeneity is classified into three categories by Bishr (1998): 1) syntactic heterogeneity, 2) schematic heterogeneity and 3) semantic heterogeneity. When spatial datasets are stored in different database systems (relational, object oriented etc.), processed using different GIS software (ESRI, Intergraph, MapInfo etc.) and presented in different geometric types (e.g. raster or vector representations), the differences between source datasets are categorised as syntactic heterogeneity. Schematic heterogeneity occurs when different data models are used to represent the same real-world objects. For example, identical entity types such as streets and

[23] https://en.wikipedia.org/wiki/Semantic_reasoner

buildings in the real world. When these entities are observed from the viewpoint of different applications, such as navigation businesses or planning agencies, the conceptual schemas about the same real-world phenomena are often different and even possibly contradicted (Volz, 2005) because of the different use case. Semantic heterogeneity arises when different disciplines or user groups have different interpretations for the same real-world object. For example, the same real-world object may have multiple different names or the same name but referring to different real-world objects.

3.2.1 RDF tackles data heterogeneous barriers in syntactic level

A common way to tackle syntactic heterogeneity is the use of international and industry standards, for example, standards published by International Organization for Standardization (ISO)[24], Open Geospatial Consortium (OGC) [25] and W3C. These standardization efforts coincided with the development of SDIs. The first-generation SDI can be traced back to the mid-1980s (Masser, 1999; Williamson et al., 2007) and since then standards have been identified as a core component. For example, the Australian and New Zealand Land Information Council (ANZLIC) defined National SDI as “an institutional framework, technical standards, fundamental datasets and clearinghouse networks" (ANZLIC, 1996) and the United States’ National SDI definition was “an umbrella of policies, standards, and procedures” (Rajabifard & Williamson, 2002).

One early driven need for SDI development was due to geospatial data collection, storage and management being costly using traditional siloed data management approaches, where reusing and sharing geospatial was problematic and data duplication efforts often occurred between agencies (Rajabifard & Williamson, 2002). Therefore, the aim of the SDI was to provide an easy way to effectively access consistent geospatial data. The first-generation SDI was viewed as data-oriented (Wiemann & Bernard, 2010, 2016; Williamson et al., 2007), and the standards used at that stage were mostly data standards that focused on the data itself and metadata (data description about data) (Masser, 1999). Masser (1999) outlined

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[24] https://www.iso.org/home.html

[25] https://www.ogc.org/

that those SDIs were explicitly national in nature, and Nebert, Reed, and Wagner (2007) concluded that most SDI activities operated independently and developed best practices based on various standards or versioned standards in silos. As a result, data and technology standards in each of these SDIs largely fit into national scope and provide a standardised data exchange method within its individual national SDI (NSDI) domain. For example, within Australia’s federated government system, each jurisdiction had different data release policies and quality compliance standards. ANZLIC adopted data standards, policies and guidelines iteratively to better manage data federation and produce nationwide products. The alignment with ISO standards came only after the 1990s when the first iteration was completed and the ISO standards came in to existence (Woodgate et al., 2017).

Alongside the NSDI developments, regional and global SDIs were also emerging (Masser, 1998). Therefore, international standards for representing and sharing of geographic information in a regional and global context were also developing. The formation of ISO Technical Committee 211 (ISO/TC 211) in 1994 was responsible for the development of international standards in the field of geographic information (Nebert et al., 2007). While ISO/TC 211 primarily developed geospatial domain standards for representing geographic features and information, the OGC which was also formed in the mid-1990s, developed many important standards in the context of the WWW and its emerging standards developed by W3C. Some of the most notable standards were web standards such as WMS, a specification for designing standard interfaces to dynamically produce maps from spatially referenced data stored in multiple sites; WFS, this standard worked in a similar fashion to WMS to allow clients to retrieve and update GML encoded geospatial data from multiple WFS; and Web Coverage Services (WCS), which defined the standard implementation for retrieval of geospatial data representing space/time-varying phenomena. Standards published by ISO/TC 211 and the OGC are still widely used in the geospatial community today for encoding and exchanging geospatial data across the Internet (Mohammadi et al., 2008; Owusu-Banahene, 2018; C. Zhang et al., 2007).

The second-generation SDIs, which started to appear in 2000 (Williamson et al., 2007), rely on open standards and OGC web service technologies for its developments (Bordogna et al., 2016; Mohammadi et al., 2008; Wiemann &

Bernard, 2010; C. Zhang et al., 2007). These second-generation SDIs evolved from data-oriented to service-oriented architectures, meaning the focus of SDI moved from the data itself to data usage and data applications (Williamson et al., 2007). For example, governmental decision-making in areas such as emergency management and natural resource management goes beyond a single organisation (Williamson et al., 2007) and geospatial datasets used to facilitate the decision-making cannot be provided by a single dataset. Therefore, it is necessary to integrate multi-sourced heterogeneous spatial datasets in the context of SDI (Mohammadi et al., 2008) to generate the required information.

There is no doubt that OGC standards have wide acceptance and are an effective way to facilitate geospatial data integration and interoperability on the syntactic level (Abbas & Ojo, 2013; Bordogna et al., 2016; Homburg et al., 2016; Janowicz et al., 2010; Owusu-Banahene, 2018). OGC standards provide a syntactical basis for data interchange (Janowicz et al., 2010; M. Lutz et al., 2009) among heterogeneous source formats and provide data interoperability at a technical level via web services and standard interfaces (Tamayo, Granell, & Huerta, 2011; C. Zhang et al., 2007), for example, service-based conflation of spatial data (Wiemann & Bernard, 2010). In addition, research has studied the direct utilization of W3C standards in the geospatial domain, and concluded that "Given that effectiveness of standards is linked to the degree of its adoption, standards by global and influential entity such as W3C are relatively more likely to succeed" (Abbas & Ojo, 2013).

In the context of Global Spatial Data Infrastructure (GSDI), Zaslavsky, Marciano, Gupta, and Baru (2000) addressed the spatial data interoperability issues by emphasising the necessity and importance of using web data interchange standards, e.g. the eXtensible Markup Language (XML) recommended by W3C. Global SDI cannot exist without national-level SDI efforts and international cooperation. However, each country has their own national and industry standards for producing and managing spatial datasets; and the efforts invested in a National Spatial Data Infrastructures (NSDI) also lead to different quality of SDIs. It is important to make national geospatial data available internationally and have universal interoperability protocols among them. Making use of the successfully proven WWW transfer protocols and data interchange standards, the proposed spatial data integration framework in this research (Zaslavsky et al., 2000) is based on XML. In this way, sources of geospatial data and services are easy for publishing and accessing geospatial data. The XML-based data interchange syntax provides great flexibility to encode geospatial data and enables different local standards to be made compatible within a common extensible framework. However, according to the work done by Koubarakis, Karpathiotakis, Kyzirakos, Nikolaou, and Sioutis (2012), the most significant work in extending XML to encode geospatial data, is the creation of GML that is still an OGC standard today.

Another notable W3C standard that has been studied and utilised to represent geospatial information is the RDF (Consortium, 2014), which is the standard data exchange format for the Semantic Web (W3C, 2020). RDF serves as a uniform structure to express information about any kind of resources on the Web, therefore, including geospatial data (van den Brink et al., 2014). All data, regardless of their original format, can be converted to RDF format (Manola et al., 2014). RDF acts as a common platform for data interchange and can be used to resolve the data heterogeneous issues between different source datasets (Sahoo et al., 2009) and server as a foundation for publishing and linking data on the Web (van den Brink et al., 2014). When data in RDF format is published on the Web according to Linked Data design principles (Berners-Lee, 2006) and interlinked with each other, the data qualify as Linked Data (Manola et al., 2014). Over the last decade, Linked Data is regarded as a best practice of the Semantic Web (Bizer et al., 2011), and it has received a lot of attention in the context of NSDIs and GSDIs to facilitate data integration and interoperability (Abbas & Ojo, 2013; Owusu-Banahene, 2018; Wiemann & Bernard, 2016; Yue et al., 2016). Linked Data is also regarded as an alternative way to disseminate geospatial data on the Web (van den Brink et al., 2014) and is seen as a key factor in the development of next generation SDIs (Huang et al., 2019).

3.2.2 RDF tackles data heterogeneous barriers at the schematic level

Resolving syntactic heterogeneous issues is only the first step towards data interoperability and meaningful data conflation, as schematic and semantic heterogeneity still stand in the way (Bishr, 1998). The novelty of RDF as a common data interchange format is that it also tackles schematic and semantic heterogeneity at the same time. Traditionally, schematic heterogeneity is resolved from the schema integration perspective in the context of database design. Schema integration refers to procedures that derive a global, unified schema from several heterogeneous data schemes, which are all designed independently (Batini, Lenzerini, & Navathe, 1986). The issues in achieving database schema integration include identifying equivalent representations of the same information in different schemas (also known as different data structures). Example solutions are (1) to define four types of "equivalence", i.e. *equal, contains, contained_in* and *overlap*, to facilitate operating inter-schema transformation and integration (Larson, Navathe, & Elmasri, 1989); and/or (2) to detect and manually correct schema conflicts resulting from incompatible specification designs. Such schema conflicts are for example, *naming conflicts, scale conflicts, structural conflicts and differences in abstraction* as categorized by Dayal and Hwang (1984). Schema integration in generic databases is already a difficult and complicated enough issue, yet the problem is even more complex in the context of geographic databases (Park, 2001).

Geospatial data not only includes thematic (attribute) data as other information domains but also contains spatial data which tells about where a real-world object is, the attribute data associated is a description regarding the real-world object. The representation of a real-world object is complicated, for example, a city could be represented as a point or a polygon (geometric element) depending on the level of abstraction. And if the city location information is recorded in different coordinate reference systems their values will not make sense to each other, for example, coordinates (positional element) recorded in *latitude/longitude* pair in one database geographic coordinate system and *easting/northing* pair in projected coordinate system in another database. In this situation, the data is difficult to analyse together unless one of the coordinate systems is projected to the other or both are projected to the same third coordinate system. Therefore, schema integration among geographic databases not only needs to deal with the *non-spatial integration (refers to domain mismatch problems in thematic and schematic conflicts)* but also *spatial integration* (Park, 2001).

As stated above, the modelling and presentation of spatial data is very complicated. According to Volz (2005), in GIS, there are multiple conceptual schemas for the same real-world entity because it is observed from different application perspectives. Therefore, multiple representations for the same real-world object occur in different geospatial databases because the data was captured by different organisations based on different conceptual schemas. These schemas are potentially contradictory and lead to multiple representations that are quite often inconsistent.

The approach proposed by Volz (2005) to achieve schema integration is called Multi-Representational Relations (MRep Relations in short). This method is not required to generate a global unified schema, but instead, takes into account the actual data to facilitate schema integration. The method is to firstly build up explicit relations between multiple representations at the data instance level, and then giving clear descriptions on whether the corresponding representations are consistent in geometric, topologic or thematic aspects. MRep Relations then builds up schema matchings between source schemas by referring to the confirmed corresponding data instances and which object class they belong to respectively in the sources. Therefore, the resulting semantic correlations between these two object classes can be set up. The approach is quite limited because it can only build up MRep Relations for point or linear features, which have approximately the same scale and rely heavily on human intervention during the process of building MRep Relations.

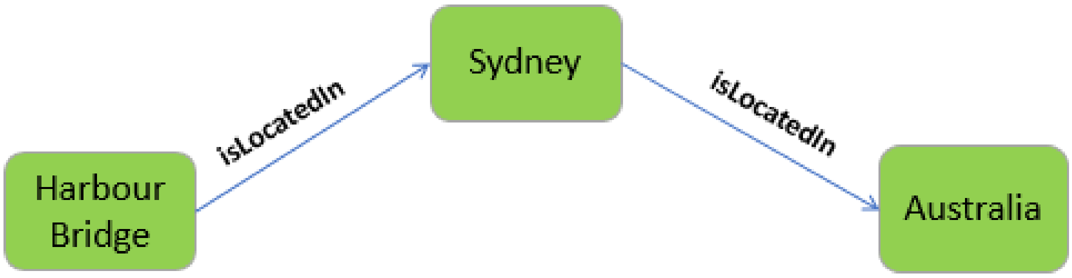
With the development of Semantic Web technologies, RDF is sought to be utilised in the process of schema integration. Even though the motivation of RDF development is to provide a standard for metadata, i.e. to encode descriptions about resources on the web, it is also capable of representing data (Decker et al., 2000). Amini, Saboohi, and Nematbakhsh (2012) developed an RDF-based data integration framework. They used RDF in the conceptual modelling process in order to provide descriptions for the integrated schema and provide a unified view of source data. Data sources are also extracted into an integrated RDF store for users to query.

In the geospatial domain, the use of RDF to present geospatial data for resolving heterogeneous data modelling issues is also highly recognised. In the study by van den Brink et al. (2014), the traditional SOA-based SDI and Linked Data are seen as complementary to each other because SDI provides large scale standardised and structured geospatial data on the Web; while Linked Data provides an open platform for sharing and combining location-related data to any kind of data once it has been converted to a linked data format.

The weakness of SDI data is that, although different datasets are standardised and structured in terms of syntax, data schematics are modelled based on shared and foreseen concepts within a silo domain. When data interoperability is required within a particular silo domain it can be assured, but when data is required to harmonise with data from another silo domain, limited harmonization will be achieved, due to the structure being too rigid for the not yet foreseen concepts and relations. This is where Linked Data can be helpful. Once geospatial data becomes part of the Web of Data, it can be integrated with other data, and data models can be interrelated and harmonised. Although the study by van den Brink et al. (2014) is from a Linked Data perspective, it is essential to know that the foundation of Linked Data is data in RDF format. As outlined by W3C (2014), under the condition that underlying data schemas differ, RDF is very helpful at facilitating data merging and supporting schema evolution, without the need for data consumer requirements to be changed. Therefore, in this respect, silo domains can continue modelling geographic information from the way they have always done to fulfil their application goals without worrying about the impact on potential data consumers.

Kuhn et al. (2014) conclude that despite issues regarding ontology design and its usage, the hierarchical (i.e. syntactic, schematic and semantic) interoperability issues have been simplified to the single common syntax, i.e. RDF. The adequate use of RDF data does not require users to understand the complex schema information. Geospatial data schemas are generally more complex than common data schemas, therefore, the simplest RDF data model (i.e. the Subject-Predicate-Object triple model or equivalent Object-Attribute-Value triple model) offers novel ways of thinking, representing and integrating geospatial data.

As explained by Decker et al. (2000), the intended role of RDF is to provide the basic data model, where no further modelling commitments are made besides the triple semantics. Therefore, attention can be fully focussed on capturing the intended meaning of the terms used in the three elements of RDF triple. When geospatial data is encoded in the RDF format (see Figure 3.3), only the semantics of node types and predicates (such as *isLocatedIn*) are needed; and the complex schema information can be retained inside the modelling organisation (Kuhn et al., 2014). RDF triples allow objects and values to be mixed, i.e. any object can play the role of value, which enables the chaining or nesting different objects together (Decker et al., 2000). For example, if we know *HarborBridge isLocatedIn Sydney* and *Sydney isLocatedIn Australia*, then graphically these two triples can be chained together, or semantically, they can be inferred *HarbourBridge isLocatedIn Australia* (see Figure 3.3).



(HarbourBridge *isLocatedIn* Sydney) & (Sydney *isLocatedIn* Australia) -> (HarbourBridge *isLocatedIn* Australia)

Figure 3.3 Geospatial RDF Triple Example

As stated by Kuhn et al. (2014), complex spatial data schemas have always been too hard to share. Yet, by presenting spatial data in RDF format, the conceptual schemata can remain internal to organisations, and the aforementioned complicated schema integration tasks can be happily replaced by the processes of ontology integration as defined in the context of artificial intelligence because they are seen as identical (Rahm & Bernstein, 2001) and ontologies are more open and manageable (Kuhn et al., 2014). Ontologies (Guarino & Giaretta, 1995) have long been seen as an effective way to resolve semantic heterogeneity issues towards the goal of geospatial data integration. There are a number of existing studies based on ontology methods (H. Arenas, Aussenac-Gilles, Comparot, & Trojahn, 2016; Cruz & Xiao, 2005; Craig A Knoblock & Szekely, 2013; Patrick & Sven, 2009; Souza, Salgado, & Tedesco, 2006; Uitermark et al., 1999; Yun, Xu, Knoblock, & Xu, 2016). Bear in mind that the design, reuse and integration of ontologies in the geospatial domain are other issues needing to be discussed and will be discussed in the next chapter.

3.2.3 RDF tackles data heterogeneous barriers in semantic level

The semantics of geospatial data has nothing to do with data formats, but instead rely on semantic descriptions for all types of geospatial data (Janowicz et al., 2010). Geospatial data simply transferred to RDF format does not contain any semantics (Vilches-Blázquez & Saavedra, 2019). This poses the question “Why RDF is more advanced than other data formats for representing geospatial data in overcoming semantic barriers?” In the comparison between XML and RDF, there are three requirements that need to be assessed to determine which format should be used in representing knowledge on the Web (Decker et al., 2000). Firstly, the format must have a universal expressive power, i.e. be able to express any form of data; secondly, the data content should be easy to read and present using different applications, i.e. guarantee the syntactic interoperability; and lastly, semantic interoperability needs to be supported, i.e. the meaning of data content should be mapped and understood between datasets. XML fulfils the first two requirements but falls short in the third one, i.e. semantic interoperability, because XML aims at presenting the documents structure and does not provide a direct interpretation mechanism for the document’s content.

As detailed by Decker et al. (2000), the meaning of data content encoded by different elements is implicit in the XML document, but it relies on another definition document to specify the intended meaning of each element or combination of elements to acquire the explicit meaning out of the XML document. Such definition documents are done either through Document Type Definition (DTD) or XML Schema. These definition documents facilitate applications to exchange and understand data. For example, if two applications have built up a specific one-to-one relation, i.e. when both applications agree on a given DTD, which provides the use and intended meaning of the document structure, the communication will be effective.

However, if conditions go beyond the one-to-one communication using XMLs and DTDs (or XML Schemas), data exchange becomes insufficient and requires more effort than necessary. The additional efforts listed by Decker et al. (2000) include 1) Reengineering the original domain data models from DTDs (or XML Schemas) because DTDs (or XML Schemas) only define the concept of elements (e.g. tag names, attribute names etc.) and their combinations used in the documents. However, meaningful data communication requires not just the mappings between the grammar but the mappings between objects and their relations. These mappings are defined in domain data models, and thus, the requirement for reengineering processes. However, the generation of DTD (or XML Schema) from the domain data models in the first place can be very different meaning the direct connection between DTD (or XML Schema) and domain data model can be lost, and therefore reconstructing the data model from a DTD (or XML Schema) becomes very difficult. 2) Based on step 1 results, the mappings between entities in the data models can be generated. 3) The mappings identified in step 2 must be translated into mapping procedures for XML documents. None of these listed steps are trivial, requiring great effort.

RDF on the other hand, also fulfils the first two requirements, but comes with more advantages compared to XML from a semantic interoperability perspective according to (Decker et al., 2000). Ground level RDF triples do not contain semantics of the data, the same as XML documents. Therefore, RDF Schema (RDFS) (Brickley, Guha, & McBride, 2014) to RDF serves as the similar functionality as XML Schema to XML, which defines particular vocabularies that should be used for RDF attributes and the types of objects these attributes should apply to. RDF used in conjunction with RDFS makes use of classes and properties for defining atomic roles for each triple, which is very powerful for representing general-purpose knowledge. The semantics can be expressed naturally through RDF's object-attribute-value structure (Decker et al., 2000). When more rich and complex knowledge about things need to be represented by RDF, advanced vocabularies or domain-specific ontologies, which are defined by ontology languages such as OWL, can be used along with RDFS. For example, as a generic language, RDF does not have specific features to represent the geometric information that is central to geospatial data (van den Brink et al., 2014). But vocabularies have been developed or extended to serve such a purpose. For instance, W3C Basic Geo[26] is an early simple vocabulary that represents point location information in the World Geodetic System 1984 (WGS84) coordinate reference system, and the more recent OGC standardised query language

[26] https://www.w3.org/2003/01/geo/

GeoSPARQL, which provides more extensive vocabularies for representing various geometric information and performing spatial queries.

Furthermore, data models that define objects and their relationships can also be encoded in RDF, and therefore the additional translation efforts explained above for using XML are not required (Decker et al., 2000). In the study by Kuhn et al. (2014), the authors compare how the data semantics are handled in the conventional way and in the form of RDF. Traditionally, data meaning is captured through a combination of a conceptual database schema and a data dictionary. In this respect, the database schema presents the structure of the data and the data dictionary specifies the intended meaning of terms.

The weakness of the database schema approach is that when data is repackaged in a different structure (such as XML), the data leaves its native environment, the intended semantics may be lost even though it is supplied with the schema information. When data is presented in the form of RDF, the triple structure is the schema, and semantics are naturally embedded in the types and predicates used in the triples and defined in the ontologies. The triple structure is the simplest a schema can ever be, there is nothing else that needs to be considered regarding the structure or schemata when the data leave their native environment. Schemata semantics are captured in traditional ways such as table relationships (cardinalities) that are stated in the same shared vocabularies as other terms in which the intended meaning for the triple elements is specified. Such shared vocabularies are explicit, and semantics are maintained the same even when outside of the data production environment.

Moreover, metadata can be stored in RDF as well. Metadata is commonly known as ‘data about data’ (Green & Bossomaier, 2002) and plays a crucial role for recording information about resources, and facilitates finding and retrieving resources. A simple example of metadata is the information about books in a library including the title, author, publisher, and year of publishing as well as the information of how to locate a specific book on a shelf among all others. Metadata for spatial data are more complex than those for generic data because information about data quality also needs to be included (Wong & Wu, 1996), i.e. *lineage, positional accuracy, attribute accuracy, logical consistency and completeness*. These metadata are critical information to help geospatial data users to understand whether the data is fit for purpose, and to what extent they can trust the data, to enable them to use the data appropriately. The same study by Wong and Wu (1996) also highlights that some spatial metadata are spatial in nature and regarded similarly to spatial data, thus they can be stored and manipulated in the same GIS system for analysis. However, as in traditional GIS practices, metadata are often captured and stored separately from spatial data with different models and formats (Kuhn et al., 2014). Metadata that is stored separately is typically text based so that humans can read it in a catalogue, but provide no machine-readable semantics (Parekh et al., 2004). When metadata are encoded in the RDF format, they are tightly integrated with spatial data. The semantics of metadata and spatial data content are both clearly defined as each RDF statement is semantically typed and annotated. This enables applications to have a better understanding of the spatial data content without the need for human intervention in order to perform analysis or reasoning automatically.

3. 3 Common Legacy Geospatial Data Formats

In the previous section, the necessity and benefits of interchanging spatial data in RDF format were discussed. Before moving to the study of RDF data conversion tools that are capable of transferring geospatial data in conventional format into RDF format, this section will review some of the most common spatial data formats. In order to fully understand the advantages and disadvantages in each conversion tool, the understanding of the original geospatial formats and each of their usages in the spatial domain is necessary.

Geospatial data represented in GIS comes in two primary types, vector and raster. Vector data comprises three primitive geometric types: point, line, and polygon. It models real-world objects using combinations of the three geometric types to represent their shapes and has their various descriptions stored separately in attribute tables (such as, object names, coordinate pairs for each geometric etc.). Vector data can be stored in many different formats, such as ESRI shapefiles, GML, KML, GeoJSON and geospatial DBMS. Raster data on the other hand, are stored in formats like GeoTIFF, and are used to model real-world objects using arrays of cells or pixels. Raster data is normally used to represent imagery, digital elevation models and surface temperature. The transformation of raster data into RDF graphs is not in the scope of this research. The following formats are examples of some well-known vector data formats and are considered input data to geospatial RDF conversion tools.

3.3.1 Geospatial DBMS

Geospatial DBMS was defined as “a full-fledged database system with additional capabilities for handling spatial data” by Güting (1994), which excluded raster database systems in the discussion. Geospatial DBMSs are mostly based on Relational DBMS (RDBMS) as most DBMSs use relational DBMS in practice (Rigaux, Scholl, & Voisard, 2001; Zhao, 2010). The driven power of geospatial DBMS development was due to a combination of the success proof that DBMSs can securely and reliably handle large volume of datasets (Shi Pu & Zlatanova, 2006; Zlatanova & Stoter, 2006) and the requirements from GIS to maintain and manipulate the ever-increasing volume of geospatial data efficiently (Rigaux et al., 2001). Many mainstream DBMSs provide spatial extensions for storing and querying geospatial data since the 1990s (e.g. Oracle Spatial and PostGIS etc.).

Geospatial DBMS provides a way to minimise data heterogeneous issues, regardless of the front-end GIS software used, as geospatial data is stored using the same geometry type, such as Oracle Spatial native geometry type SDO_GEOMETRY etc. The development of mainstream spatial DBMSs strictly conforms to OGC standards (S Pu, 2005). For example, mainstream geometric types are based on OGC Abstract Specifications and OGC Simple Specification for SQL (SFS) that define standard SQL schema for querying simple geospatial features in the DBMSs.

3.3.2 ESRI Shapefile

The Shapefile format was developed by ESRI[27] for the storage of vector data (ESRI, 1998). It supports point, line and polygon features together with corresponding attribute information. The structure of a shapefile includes three mandatory files: 1) a main file (.shp) that contains the geometry of geospatial features; 2) an index file (.shx) that stores the index of the feature geometry; and 3) a dBASE table (.dbf) that

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[27] Environmental Systems Research Institute, Inc. (ESRI) - https://www.esri.com/en-us/about/about-esri/overview

stores additional attributes, which can be joined to geometry features in a one-to-one relationship. There are other extension files that can relate to a shapefile but are not mandatory, for example, a projection file (.prj) that stores coordinate system information and a metadata file (.xml) for storing relevant information about the shapefile etc.

Shapefiles exclude topological information for spatial features hence the processing overhead is less. Each shapefile only contains one geometry type, for example, either point, line or polygon. The maximum size of a shapefile is 4GB (Růžička, 2016), so it requires less disk space and is easier to read and write. This makes shapefiles suitable for small to medium-size map applications. ESRI published the technical specifications of Shapefile openly so users can create their shapefile even without using ESRI software. It is widely used in the GIS industry and accepted as an industry standard. Almost all commercial applications and open source applications can work with shapefiles.

3.3.3 XML

The Extensible Markup Language (XML)[28] has officially became a W3C recommendation since 1998 (W3C, 1998) and has been adopted universally as a data representation format (Nurseitov, Paulson, Reynolds, & Izurieta, 2009). It was developed based on the older standard format Standard Generalised Markup Language (ISO 8879) (Smith & Stutely, 1988), which is the markup language for structured text documents, that simplifies documents so that they are suitable for representation on the Web (Lehto, 2000; W3C, 1998). Basically, any structured information that is to be shared across the Internet can be encoded and transferred using XML, such as a document you have written, a book you have read, or an invoice for an item you purchased. The XML specification only defines the logical structure and syntax of the language, none of the individual tags used in the markup is specified. Therefore, any user can create their own tags/markups for the encoding of information or data.

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[28] Extensible Markup Language (XML) 1.0 (Fifth Edition)
https://www.w3.org/TR/2008/REC-xml-20081126/

The main advantage of XML is that XML can be used across various domains (Lehto, 2000; Nurseitov et al., 2009). The geospatial domain is one that quickly adopted XML to encode geospatial information - not just for encoding descriptions about geospatial data but also geospatial data itself (Lehto, 2000). Lehto (2000) discussed some XML related standards developed (e.g. Scalable Vector Graphics (SVG)) by W3C that can be utilised when designing web-based geospatial applications. Zaslavsky et al. (2000) demonstrated how an XML-based information integration framework can be extended for geospatial information integration and enable global geospatial data interoperability. Many of the international geospatial data standards are developed based on the XML language, for example, ISO specifies the encoding rules for interchange of geographic information in the set of International Standards known as “ISO 19100 series” which is XML-based (ISO, 2011). OGC also publishes many of their standards based on XML, such as GML, KML, and OGC web services including WCS, WMS and WFS etc.

3.3.4 GML

Geography Markup Language (GML) improves data interoperability and exchange between different systems across the Internet. GML is “an XML grammar written in XML Schema for the description of application schemas as well as the transport and storage of geographic information” (Portele, 2012). It was developed by OGC as an implementation standard to encode geographic information including both spatial and non-spatial attributes of geographic features regardless of application domains and operating systems.

The development of GML can be traced back to Cuthbert et al. (2000), when it was commonly known as GML 1. Although lacking in functionality, GML 1 laid the foundation for the further development of GML 2 (Cox, Cuthbert, Lake, & Martell, 2001) and the most current version GML 3 (Portele, 2007, 2012), which is a better and more comprehensive approach for modelling, storage and transferring of geographic information.

GML 2 is based on the OGC Abstract Specification, which models the world in terms of features. A geographic feature is defined as a feature “associated with a location relative to the Earth” and a feature is “an abstraction of a real-world phenomenon" (ISO 19101). Features constructed by GML 2 are simple features whose "geometric properties are restricted to 'simple' geometries for which coordinates are defined in two dimensions and the delineation of a curve is subject to linear interpolation" (Cox et al., 2001). The implementation of GML 2 follows the geometry model defined in OGC Implementation Specifications, therefore points, line strings and polygons are used to represent traditional 0, 1 and 2-dimensional geometries that are defined in a two-dimensional spatial reference system. In addition, feature collections in which geometries are collections of other geometries, such as multi-point, multi-line string and multi-polygon collections or mixed type collections (e.g. collection of multi-points and multi-polygons) are also used as allowed in the simple feature geometry model.

GML 3 incorporates more functionality than its predecessors. It allows for more complex feature types to represent real-world phenomena and provides more explicit support for feature properties and complex values, "including features with complex, non-linear, 3D geometry, features with 2D topology features with temporal properties; dynamic features; and coverages and observations" (Cox et al., 2002). The expanded GML 3 base schemas are over eight times as large as the GML 2 base schemas because of the extensive functionality available. But it is not necessary to use all the definitions as users can select a subset of GML that is most appropriate and sufficient enough to their application needs. GML is also flexible and extensible for users to define their own tags or elements to describe geographic features. GML 3 is backward compatible with previous versions.

GML provides a way to minimise geospatial data heterogeneous issues of the Internet. Geographic data can be encoded in a unique way and distributed across the Web regardless of its information domains, process methods and storage types. GML encoded data is self-descriptive, can serve as a mechanism for data discovery, retrieval and exchange. Different applications use GML as a common language to communicate with each other and exchange information, and therefore improve data interoperability.

3.3.5 KML/KMZ

Keyhole Markup Language (KML) is an OGC standard used to encode and transfer representations of geographical data for display in an earth browser (Wilson, 2008). Similar to GML, KML is also based on XML grammar and it uses simple geometric elements derived from GML 2, including point, line string and polygon, to represent geographic features. Although, additional harmonization of KML with GML is still required to use the same geometry representation in the future (Wilson, 2008).

KML is complementary to GML. GML is designed for encoding and transporting the contents of geographic features, and therefore does not provide any instructions for how to display the data; whereas KML is focused on the visualisation of geographic features in Geobrowsers. A Geobrowser is an application that is capable of dealing with georeferenced data across the Internet. It can be a desktop program like Google Earth (desktop version) or a web browser embedded with an application to deal with geospatial data such as Google Maps (Sandvik, 2008).

KML provides a standard way to express what and how geographic features can be annotated and visualised in web-based maps and mobile maps that conform with the traditional two-dimensional maps (2-D). It also standardises the representation of geographical features in three-dimensional (3-D), such as on a 3-D virtual globe. Examples are Google Earth and Microsoft Virtual Earth. There are many functionalities that can be defined by KML documents besides geometric information. For example, it can define satellite images or base maps as overlaying layers that can be attached to globe ground. These images and base maps serve as background layers to provide contextual information for the analysis of geospatial data. KML can also define different camera positions so geo-features can be viewed from different angles, giving users a 3-D experience as they can control where to go and what to look at.

Users dealing with KML files will come across another term KMZ, which compresses KML documents and their relevant files using the ZIP format. The KMZ package reduces the size of KML files and their support components. In this way, multiple files can be managed as a single entity to improve efficiency and make it easier to transfer data over the Web. There is no extra requirement for applications to deal with KMZ format; applications like Google Earth can directly read and write KMZ documents. Otherwise. KMZ files can be unzipped before import into applications using compression utilities, such as WinZip© on Windows and MacZip© for Macintosh etc.

3.3.6 JSON

JavaScript Object Notation (JSON) [29] has been an Internet Engineering Task Force (IETF) standard since 2006 (Crockford, 2006). It is a lightweight, text-based data interchange format for encoding structured data. It is designed to be language-independent, but is essentially a subset of JavaScript, and therefore, is directly supported inside JavaScript and is best suited for JavaScript-based applications. The performance of JSON is significantly faster than XML in the case of transmitting large amounts of objects according to the study of Nurseitov et al. (2009). JSON has recently become one of the most popular data exchange formats on the Web due to its simplicity and because it can be easily read by both human and machines (Bourhis, Reutter, Suárez, & Vrgoč, 2017; Peterson, 2016).

3.3.7 GeoJSON

GeoJSON[30], as can be implied from the name, is developed based on JSON and specifically for interchanging geographic data. GeoJSON was initially published in 2008 (Butler et al., 2008) and has since steadily grown into one of the most common geospatial vector data formats (Gillies, Butler, Daly, Doyle, & Schaub, 2016). As inherited from JSON format, the GeoJSON objects are constructed in a very simple structure of key/value pairs. It can be easily read and parsed by both humans and machines. GeoJSON supports geometric types including (Multi-)Point, (Mulit-)LineString, (Multi-)Polygon and GeometryCollection. A GeoJSON object can be any type of the geometries, or a feature containing both geometry and attribute, or a collection of features. All GeoJSON coordinates are defined in one geographic coordinate reference system using the WGS84 datum, with longitude and latitude units of decimal degrees (Gillies et al., 2016).

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[29] https://tools.ietf.org/html/rfc7159

[30] https://tools.ietf.org/html/rfc7946

3.3.8 Summary

This research proposes geospatial data to be presented in RDF format as the foundation towards building an effective AGDC system. While there are already significant works that had been done to standardise the representation and exchange of geospatial data, there still exists various data formats to meet different needs.

Proprietary GIS have their own native file format, such as ESRI ArcGIS, Intergraph MapInfo and AutoCAD etc. The technical specifications for Shapefiles, developed by ESRI for its ArcGIS suite products, are openly available. Due to the influence of ESRI in the GIS industry, shapefile format is adopted ubiquitously thus becoming an industry standard. Commercial GIS applications that have their own proprietary native data formats, also provide tools to import other data sources stored as shapefiles and can export its data in shapefile format for other applications to process. Well-known open source GIS applications, such as QGIS, can all read and write in the shapefile format. The shapefile format is a standard way to minimise data source heterogeneous issues due to different GIS software having their own data formats. Various source datasets stored in shapefile format can be opened in a GIS application at the same time for visualisation and analysis thus improving data interoperability.

The drawback of shapefiles is that they can only store up to 4GB data in a single shapefile and each shapefile only allows one type of geometry. If a project involves a large amount of data and requires multiple types of geometries for analysis at the same time, the performance of the GIS would decrease dramatically. Therefore, the development of a geospatial databases is aimed to provide a solution for such situations. Traditional DBMSs have been demonstrated to manage and manipulate large volume datasets reliably and securely. Geospatial DBMS based on traditional DBMS combines its powerful data processing ability with specific extensions to deal with the complex spatial geometric data types. A geospatial DBMS can handle simple features such as points, lines and polygons as well as complex features. It also provides spatial operations on those features such as intersections, unions etc. within the system so spatial queries and analysis can be done inside the DBMS, taking off some of the process burden from GIS. Geospatial DBMS serves as a centralised storage system within an enterprise. It allows spatial data to seamlessly integrate with other enterprise data, making it possible to spatially enable many enterprise applications.

In contrast to the centralised data management system, there is a continuous trend for discovery, retrieval and integration of geospatial data across the Web. Therefore, OGC's GML specifications provide a standard way for encoding and transporting distributed geospatial information on the Web. Regardless of the underlying dataset formats and storage systems, they are all encoded and transported in a unanimous form, minimising the data heterogeneous problems on the Internet. However, GML only focuses on the content of geographic information, it does not provide a way for encoding the visualisation of the data, this is achieved using KML. KML was developed as a proprietary format by Google for its Google Earth and Google Map products. It allows users to view their own geospatial data by overlaying it on top of base maps or satellite imagery. This function provides a better visualisation experience to users and gives them a contextual understanding of the data (Sandvik, 2008). Google submitted the KML specification to OGC and it became an OGC standard in 2008. As one of the many OGC standards, it fits within the OGC family and therefore promotes broader implementation of KML and greater interoperability among earth browser content and context sharing (Wilson, 2008). In conclusion, GML contains more sophisticated data models and geometries to represent real-world objects, but it only encodes the content, not the visualisation of the geospatial data. KML can encode the content as well as visualisation of the geospatial data but only limited to simple features. There is further development required for KML to be able to represent complex geometries (Chow, 2011).

As each standard format has its own strengths and weaknesses, geospatial data are encoded in these variety formats depending on different organisations' requirements and needs. Therefore, the data heterogeneous issues existing in syntactic, schematic and semantic levels causing many difficulties towards automatic geospatial data conflation.

The RDF format can effectively resolve geospatial data heterogeneous problems in syntactic, schematic and semantic levels, and this is identified and justified in the Section 3. 2 of this chapter. Once geospatial data is transformed into RDF formant based on defined ontologies, the geospatial RDF triples are enriched with explicit semantics enabling conflation rules to reason on top of them and make conflation decisions automatically. Understanding geospatial data encoded in the above-mentioned various formats and effectively converting them into RDF format, are concrete steps towards building the proposed AGDC system based on Semantic Web technologies. In the next section, the study is focusing on tools available for converting geospatial data into RDF format.

3. 4 Geospatial RDF Data Converter

3.4.1 Introduction

Similar to the usage pattern of Semantic Web technologies (including RDF, Ontology and SWRL rules) in geospatial domain by far identified in this research, which is generally stem from the success applications in computer science domains and generic data, and then adopted and extended in geospatial domain and geospatial data. The RDF data conversion tools are also first developed within computer science domains and applied in general data. There are two prevailing methodologies that have been used for transforming relational data into RDF data. The first method is Direct Mapping of Relational Data to RDF[31] which has become a W3C recommendation since 2012. This method maps relational tables to classes defined by an RDF vocabulary and mapping table attributes to RDF properties. The class names and properties are directly extracted from the relational database schemas. For example, on the left side of Figure 3.4, two relational tables are presented, each having a single-column primary key and a foreign key building the relationship between them. Using the direct mapping method, a series of RDF triples is produced on the right-hand side. The table names are each mapped to an RDF class (e.g. rdf:type <People> and rdf:type <Addresses>) while RDF properties are directly extracted from table columns (e.g. <People#fname>).

[31] https://www.w3.org/TR/2012/REC-rdb-direct-mapping-20120927/

People

PK		→ Address(ID)
ID	**fname**	**addr**
7	Bob	18
8	Sue	**NULL**

Addresses

PK		
ID	**city**	**state**
18	Cambridge	MA

```
@base <http://foo.example/DB/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .


<People/ID=7> rdf:type <People> .
<People/ID=7> <People#ID> 7 .
<People/ID=7> <People#fname> "Bob" .
<People/ID=7> <People#addr> 18 .
<People/ID=7> <People#ref-addr> <Addresses/ID=18> .
<People/ID=8> rdf:type <People> .
<People/ID=8> <People#ID> 8 .
<People/ID=8> <People#fname> "Sue" .

<Addresses/ID=18> rdf:type <Addresses> .
<Addresses/ID=18> <Addresses#ID> 18 .
<Addresses/ID=18> <Addresses#city> "Cambridge" .
<Addresses/ID=18> <Addresses#state> "MA" .
```

Figure 3.4 Direct Mapping Relational data into RDF data (M. Arenas, Bertails, Prud'hommeaux, & Sequeda, 2012)

Another method is using the RDB to RDF Mapping Language (R2RML)[32] so relational data can be transformed into an RDF graph by mapping to a user provided vocabulary. The R2RML method provides a more flexible way of choosing structured vocabularies than the direct mapping method. The resulting RDF data will therefore be semantically enriched and more appropriate to users' specific needs. It became a W3C recommendation in 2012. Many relational databases to RDF conversion tools have been developed based on these two methodologies, such as the D2RQ platform (Bizer & Seaborne, 2004; Eisenberg & Kanza, 2012), OpenLink Virtuoso (Erling & Mikhailov, 2009) and Triplify (Auer, Dietzold, Lehmann, Hellmann, & Aumueller, 2009). However, these did not include how to transform geospatial information stored in the relational database into RDF graphs.

The first tool available for converting geospatial data stored in a spatially enabled relational database into an RDF graph was Geometry2RDF (Vilches-Blázquez et al., 2010) which applied direct mapping methodology. There is also existing a large amount of geospatial data stored in many different GIS standard formats as reviewed in the Section 3. 3 (e.g. ESRI shapefile, KML, GeoJSON) to accommodate various users' needs, such as visualisation on a map or overlaying layers for spatial analysis. In order to transform geospatial data stored in those GIS formats, Shp2GeoSPARQL (Saavedra, Vilches-Blázquez, & Boada, 2014) and TripleGeo (Patroumpas, Alexakis,

[32] https://www.w3.org/TR/r2rml/

et al., 2014) were developed to extend functionality of Geometry2RDF to accommodate such needs and adding the capability of presenting geometric RDF triples compliant with OGC GeoSPARQL standards.

These three tools each have their own advantages and drawbacks. Geometry2RDF generates geometric RDF triples according to NeoGeo vocabulary so the geometries are structured which can be handled by regular SPARQL queries. But the coordinate reference system (CRS) of the geometries are restricted to WGS84. Shp2GeoSPARQL and TripleGeo are both extended to present geometric RDF triples according to GeoSPARQL vocabulary, giving the advantage of defining geometries in any CRS. But there were very few triple stores implementing the GeoSPARQL standard at the time therefore restricting their wide adoption. GeomRDF was developed by Hamdi et al. (2015) in order to overcome the limitations of Geometry2RDF, Shp2GeoSPARQL and TripleGeo combined. On the other hand, GeoTriples was developed based on the R2RML approach (Kyzirakos et al., 2014), enabling customised mapping of various geospatial data to geometric RDF graphs, so it can publish geospatial data into RDF triples according to GeoSPARQL vocabulary or any vocabulary defined by users. The rest of the section will introduce these conversion tools with more details and compare their properties.

3.4.2 Geometry2RDF

Geometry2RDF[33] was developed under the GeoLinked Data initiative which aimed at enriching the Web of Data by adding Spanish national geospatial datasets. The tool enables geospatial data stored in spatially enabled DBMS (either Oracle Spatial or MySQL spatial databases) to be converted into RDF, as shown at the left hand side of Figure 3.5. When the input is from Oracle Spatial, it relies on Oracle STO UTIL to transform the GEOMETRY column into GML, where each row of a table represents a distinct feature. Then the Geometry2RDF library (sits in the middle of Figure 3.5) converts the GML into a set of RDF triples. On the other hand, if input is from MySQL spatial databases, and the geometric information is stored in the *GEOMETRY* column is presented in WKT format, there is no function required to generate GML, the WKT will be extracted and fed directly into Geometry2RDF to

[33] http://mayor2.dia.fi.upm.es/oeg-upm/index.php/en/technologies/151-geometry2rdf/

generate RDF triples. After the RDF triples had been defined (whether in GML or WKT), they are processed by GeoTools[34] to retrieve geometry and perform coordinate transformation if required. Finally, Apache Jena[35] (shown at the right hand side of Figure 3.5) is used to generate the final geospatial RDF triples which are compliant with the WGS84 vocabulary and the GML ontology (Vilches-Blázquez et al., 2010). The geometric types that can be dealt with by Geometry2RDF tools are point and line string. Since Geometry2RDF follows the direct mapping approach, mapping to other custom vocabularies is not supported.

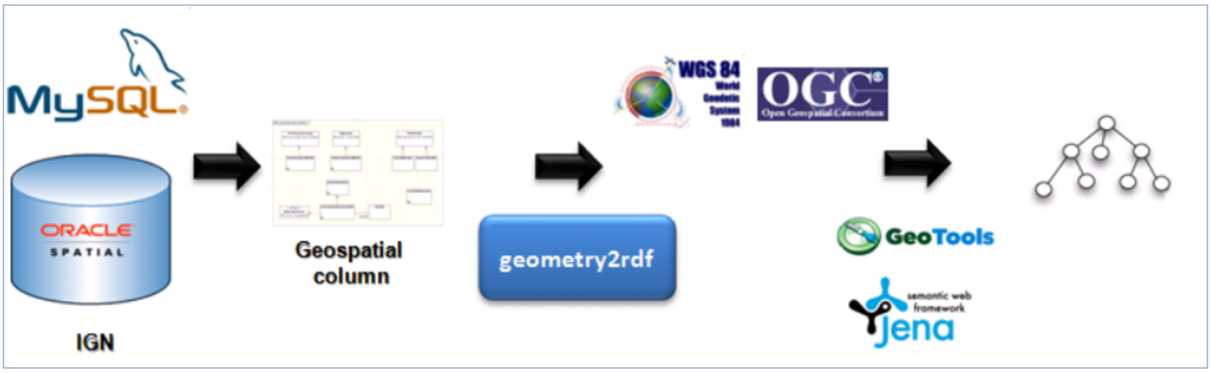

Figure 3.5 Geometry2RDF framework of transformation of the geospatial information into RDF (OEG, 2019)

3.4.3 Shp2GeoSPARQL and WFS2GeoSPARQL

Shp2GeoSPARQL[36] is a Java library developed as an extension of Geometry2RDF to transform geometric information from shapefile format (Saavedra et al., 2014). It also advances the geospatial RDF triples by generating them according to the GeoSPARQL ontology. It has been further developed into a web application giving users more friendly operation experience (Vilches-Blázquez & Saavedra, 2019). While geometry and spatial relations associated with geographical features are still transformed according to the GeoSPARQL vocabulary, it provides additional functionality allowing users to upload domain specific ontologies (common and

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[34] GeoTools is an open source Java library that provides tools for geospatial data. https://www.geotools.org/

[35] Jena is a free and open source Java framework for building Semantic Web and Linked Data applications. http://jena.apache.org/

[36] A Java console tool to convert geometries from shape files to RDF using GeoSPARQL standard.

shared vocabularies). Therefore, the RDF triples generated are with explicit meanings in the relevant domain. Furthermore, the Shp2GeoSPARQL web application allows users to choose whether it is needed to re-project geometries into another spatial reference system, to calculate centroid point along the transform processes if the geometric type is polygon and if needed to include internal spatial relationships using GeoSPARQL vocabulary.

WFS2GeoSPARQL[37] is another RDF transform element developed by Vilches-Blázquez and Saavedra (2019) to transform geospatial data retrieved from WFS services into RDF triples. It was also modified and enhanced based on the Geometry2RDF library and presented to users as a web application. It takes WFS GetCapabilities, URI of the get capabilities request, as source input whose underlying data format can be spatial DBMS, ESRI shapefile, GeoJSON, CSV or DXF etc. Other functionalities are similar to Shp2GeoSPARQL application. Both Shp2GeoSPARQL and WFS2GeoSPARQL tools provide optional function for linking other sources published on the Linked Open Data (LOD) [38] cloud.

3.4.4 TripleGeo

TripleGeo is an Extract-Transform-Load (ETL) utility[39] developed under the GeoKnow[40] project. The tool was developed based on Geometry2RDF open source and overcome some deficiencies inherited (Patroumpas, Alexakis, et al., 2014). Those deficiencies include the RDF model not compliant with OGC GeoSPARQL standard, not supporting thematic attributes transformation and limited input/output formats. As an ETL tool, TripleGeo enabled users to: 1) Extract spatial data from broader sources, including spatially enabled DBMSs (Oracle Spatial, MySQL, PostGIS and IBM DB2 with spatial extender), ESRI shapefile, GML and KML; 2) Transform extracted data into geospatial RDF triples according to different geometry vocabularies. Users can choose the WGS84 vocabulary or the Virtuoso RDF

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https://github.com/jasaavedra/shp2geosparql

[37] https://github.com/jasaavedra/GeoLOD

[38] https://lod-cloud.net/

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

[40] http://geoknow.eu/Project.html

vocabulary for representing point features or choose the GeoSPARQL vocabulary for more complex geometric types (including points, linestrings and polygons) depending on their targeting RDF store options; 3) Load RDF triple results into the target RDF store. It can output RDF triples into a local file with more format options, including RDF/XML (default), RDF/XML-ABBREV, N-Triples, N3 and Turtle, giving a flexible selection of RDF stores and swifter loading into the store. In addition, it can extract thematic attributes such as names or types with features and allows on-the-fly coordinate reference systems reprojection. It can deal with most common spatial data types, such as point, (multi-)linestrings, and (multi-)polygons.

TripleGeo inherits several open-source tools and library dependencies from Geometry2RDF, such as Apache Jena, GeoTools, GDAL/OGR[41] and Java Topology Suite (JTS)[42]. It has been implemented with these Java classes performing specific tasks in a modular fashion as shown in Figure 3.6. The modular implementation allows more utilities to be further developed without affecting its existing functionality. Targeting improvements, such as converting more complex geometric types (e.g. geometry collections), support input source from RESTful API (e.g. for web-accessible data), and provide users with the ability to map data to user-defined ontologies (Patroumpas, Alexakis, et al., 2014).

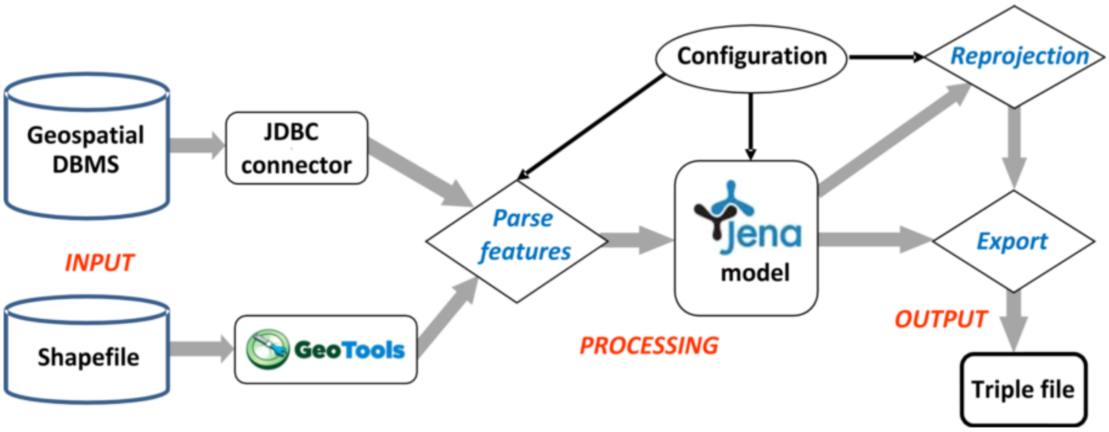

Figure 3.6 Processing flow diagram for ETL utility TripleGeo (Patroumpas, Alexakis, et al., 2014)

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[41] https://www.osgeo.org/projects/gdal/

[42] https://github.com/locationtech/jts

Most of the above-mentioned possible improvements have been achieved in the further development of TripleGeo by Patroumpas et al. (2019). It supports all OGC primitives for 2-dimensional geometries, including Geometry Collection and it allows the users to map thematic attributes to a user-specified ontology. In addition, it is capable of Multi-thread Execution and Parallelised Execution which makes it the first scalable RDF transformation tool among other geospatial RDF converters. Most importantly, it is the first tool allowing reverse transformation of geometric RDF triples into traditional GIS formats (currently only supports CSV and ESRI shapefile formats).

3.4.5 GeomRDF

GeomRDF[43] was developed to provide users with an easy way to transform traditional geospatial data into RDF. It can be used as a stand-alone conversion tool or implemented as a module in the Datalift Platform[44] to publish geospatial data as linked data. It takes geospatial data in ESRI shapefile, geospatial DBMS and GML formats as input, as shown in Figure 3.7. The system then classifies properties extracted from the inputs into either geometric or thematic type. The RDF Builder module will then generate RDF triples for geometric and thematic type separately. The generation of geometric RDF triples is according to the Ontology of Geometric Primitives[45] which is a vocabulary reusing and extending the GeoSPARQL and NeoGeo ontologies, giving a very precise description of vector geometry types. Therefore, the geometric RDF triples created by GeomRDF can be defined in any CRS and GeoSPARQL compliant systems; or defined in WGS84 with structured geometries that can be handled by regular SPARQL queries. While generating thematic RDF triples, the default setting of GeomRDF is using property names as predicates. GeomRDF does not support mapping thematic attributes to domain specific ontologies or custom ontologies. The matching and replacing of default predicates to ontology predicates can be done by another module in the Datalift Platform (Hamdi et al., 2015). GeomRDF can deal with complex geometries.

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[43] https://github.com/fhamdi/GeomRDF

[44] https://datalift.org/

[45] http://data.ign.fr/def/geometrie/20190212.en.htm

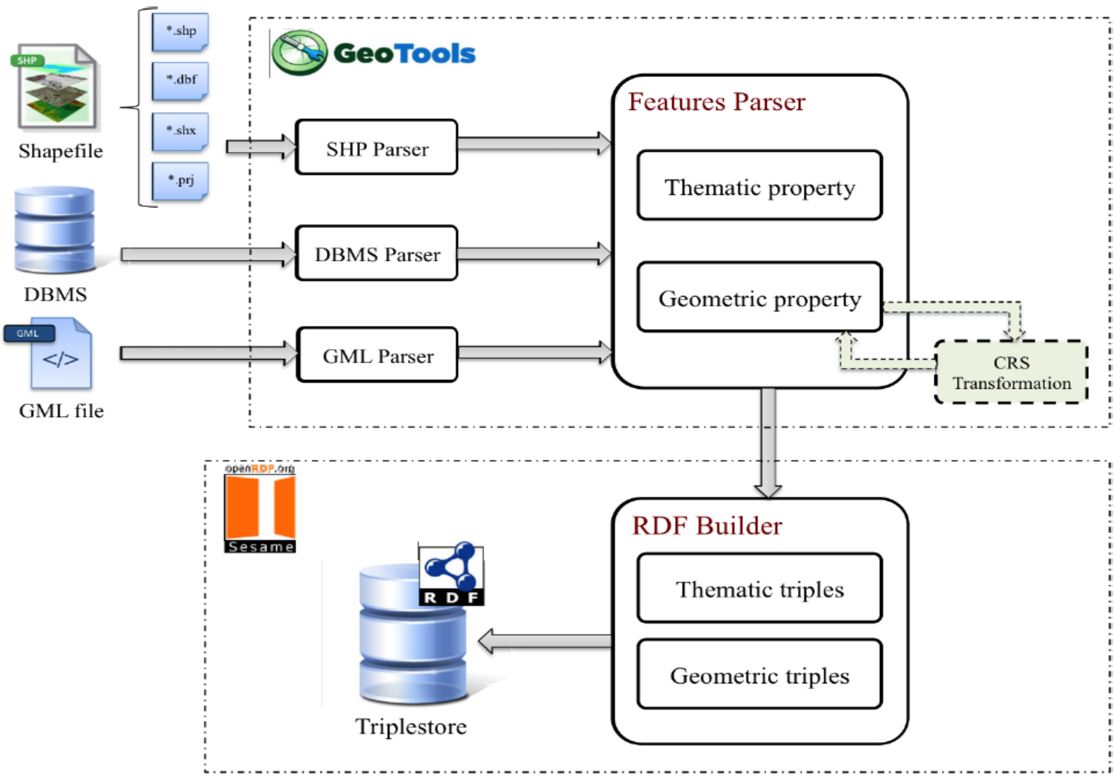

Figure 3.7 GeomRDF Components (Hamdi et al., 2015)

3.4.6 GeoTriples

GeoTriples[46] is an open source tool developed based on the D2RQ platform that utilises the R2RML method for generating RDF mappings for spatially enabled relational databases (e.g. PostGIS and MonetDB). The R2RML was extended to deal with the specificities of geospatial information as they may be modelled using different data models, such as hierarchical rather than relational, and stored in different GIS formats, such as ESRI shapefile and KML (Kyzirakos et al., 2014). A further development to GeoTriples is also using an R2RML extended mapping language RDF Mapping Language (RML) (Dimou et al., 2014). RML extended R2RML by keeping its mapping definitions but excluding the database-specific references from the core model, so that its input can be referred to a broader set of sources (such as semi-structure data XML and JSON etc.) instead of a relational table only (Kyzirakos et al., 2018). As shown in Figure 3.8, the main components of GeoTriples include a Connector (the left side component in the middle section of Figure 3.8), a stSPARQL/GeoSPARQL Evaluator, a Mapping Generator and a

46 http://geotriples.di.uoa.gr/

Mapping Processor. For each type of input data, a connector is used to access and process transparently. Then the Mapping Generator is responsible for the automatic generation of R2RML or RML mapping documents. The mapping is enriched with well-known vocabularies like GeoSPARQL and stSPARQL, or users can choose to edit the mapping documents with different vocabularies based on their needs (completed by the Ontology-based Data Access Engine, i.e. stSPARQL/GeoSPARQL Evaluator). Finally, the Mapping Processor takes into account the R2RML mapping or RML mapping documents and generates the desired RDF triples.

GeoTriples also extends R2RML and RML mapping languages with new classes and properties. This allows some on-the-fly transformation functions according to stRDF or GeoSPARQL vocabularies, for example, during the process of transforming geospatial data into RDF, GeoTriples can also calculate the length of a line or the area of a polygon based on the input geometries on-the-fly. In addition, the inexplicit topological, directional or distance relationship between two spatial objects can also be derived during the process.

In the case of users who do not want to explicitly transform source data into linked data, GeoTriple provides the option of using generated mappings in the Ontop-spatial system to virtually view them as linked data. Ontop-spatial can perform on-the-fly GeoSPARQL-to-SQL translation on top of geospatial databases (Bereta & Koubarakis, 2016).

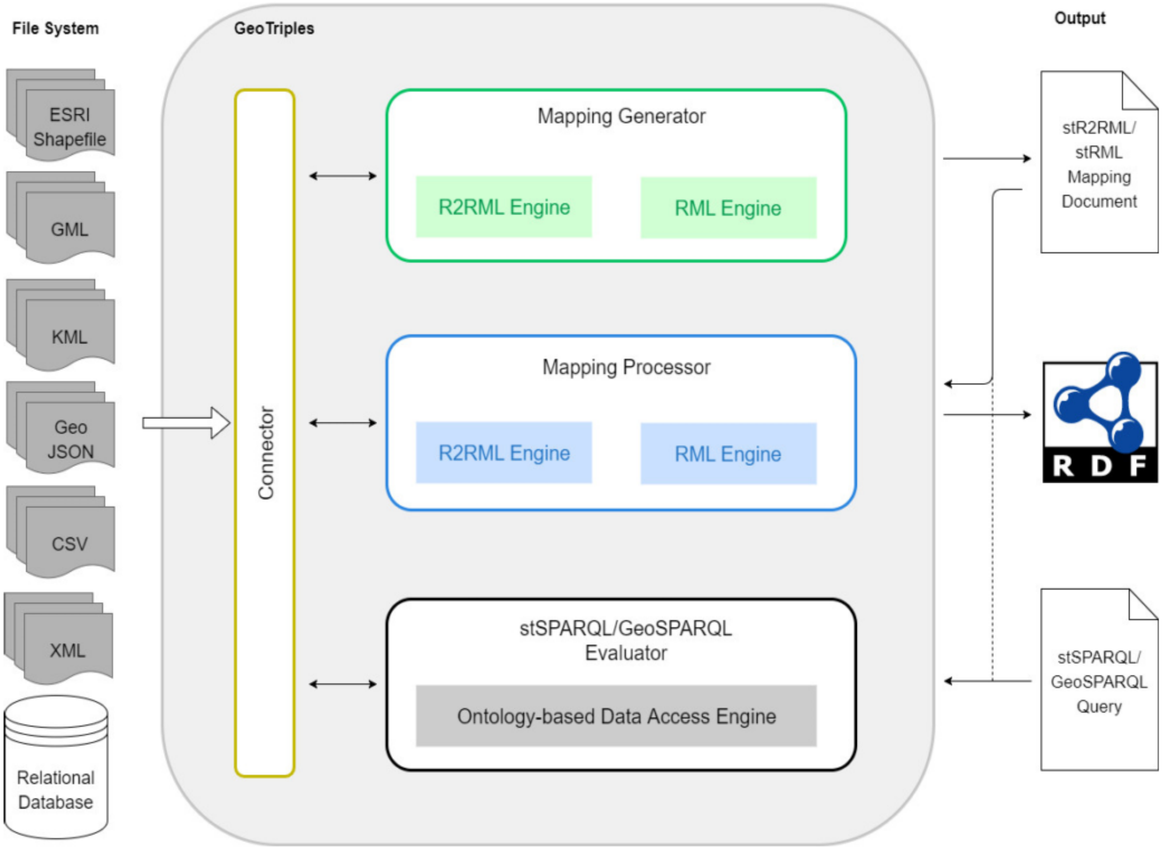

Figure 3.8 The architecture of GeoTriples (Kyzirakos et al., 2018)

3.4.7 Summary

The study of geospatial RDF conversion tools provides essential information and knowledge to this research, and beyond, about what tools are available for converting heterogeneous geospatial datasets into geospatial RDF triples.

In summation, the development of the geospatial RDF conversion tools started as early as 2010 with the appearance of Geometry2RDF (Vilches-Blázquez et al., 2010). It followed the trend of transforming legacy data stored in relational databases into RDF triples by transforming geometric information stored in spatially enabled databases into geometric RDF triples. The Geometry2RDF tool is no longer maintained but it lays the development foundation for its extension tools Shp2GeoSPARQL (Saavedra et al., 2014) and TripleGeo (Patroumpas, Alexakis, et al., 2014) which have both improvement recently.

The new development of Shp2GeoSPARQL came along with a similar application WFS2GeoSPARQL in order to directly take inputs from results of WFS web services (Vilches-Blázquez & Saavedra, 2019). TripleGeo on the other hand, firstly provides the functionality of reversely converting linked data enriched geometric RDF triples into traditional GIS data (in CSV and ESRI shapefile formats). Given there is a large amount of GIS legacy data available and the majority of GIS software still relies on inputs from traditional GIS formats, the transition into utilised geospatial RDF triples in geospatial data analysis and manipulation will be a long course. To be able to transform geospatial data into RDF triples and then transform back to its original format after enrichment, demonstrating the enriched geospatial data can benefit the current work routines will provide incentive to more and more current GIS users to adapt to RDF data format. GeoTriples developed using a different methodology have also has recently realised improvements (Kyzirakos et al., 2018). GeoTriples further extends R2RML and RML mapping languages with new constructs giving users options to infer new information on-the-fly, such as calculating length of a line or area of a polygon, or the topological relationships between spatial objects etc.

A common trend among these geospatial RDF conversion tools is that they are compliant with the GeoSPARQL standard and giving users the option of using user-defined ontologies. Another common development is that the tools are providing users with GUIs so they are more user-friendly and reduce the complexity for GIS users who might not be familiar with programming. The development history of geospatial RDF conversion tools is not very long, and these tools still require further development before they are mature and well used by GIS users. Nonetheless they are providing users with different options to choose from in order to cater for different users' needs.

One of the main requirements in this research's case study is to transform source geospatial datasets (mainly stored in shapefile format) into RDF triples based on custom ontologies. All of the reviewed conversion tools are able to take shapefile format as input, which is not surprising because the shapefile format is the default GIS industry standard format as discussed in Section 3. 3; and most of the tools (including Shp2GeoSPARQL, TripleGeo and GeoTriples) provide options for choosing custom ontologies in their latest developments. Therefore, multiple choices are available to meet this research requirement providing great flexibility to the research for transform source datasets into RDF format.

This research can be extended in the future using other geospatial data formats, and while out of scope, it is acknowledged that current geospatial RDF converters are able to deal with the majority of geospatial data formats in line with the common data format review in Section 3. 3, i.e. geospatial DBMS, XML, KML/KMZ, GML, JSON and GeoJSON in addition to shapefile format. Another important acknowledgement is that the current geospatial RDF converters are able to let a user choose their custom ontologies during the conversion process to meet different applications' requirements. Furthermore, all the reviewed converters comply with the OGC GeoSPARQL Standard, providing a pathway for geospatial RDF triples across various applications to semantically communicate and exchange if GeoSPARQL ontology is chosen in the conversion process. In the future, if all geospatial RDF converters are making standardised efforts and standardising geospatial RDF triples becomes an industry-wide activity, the data heterogeneous issues will be minimised and automatic geospatial data conflation will become more easily achievable.

3. 5 Management of Geospatial RDF

3.5.1 Introduction

Questions raised right after the conversion of geospatial RDF triples is how to manage those triples and how to query or use them during the geospatial data conflation process. Therefore, this section is to study the management systems of geospatial RDF triples, also known as geospatial triple stores.

When reviewing the triple stores for storing and querying geospatial RDF, it is essential to understand the vocabularies and ontologies developed for geospatial data. As RDF is a generic interchange format for encoding any data, it has no features for representing geospatial data specifically (van den Brink et al., 2014). Organisations when developing triple stores for geospatial data each have their own approaches to define ontologies for storing geospatial data and query predicates for retrieving such data, leading to geospatial RDF data that are not able to be indexed and queried properly across platforms (Battle & Kolas, 2012). Therefore, the need for standardised vocabulary and query languages is necessary.

3.5.2 Geospatial RDF vocabularies

An early attempt was performed by the W3C Semantic Web Interest Group (SWIG) which developed the Basic Geo Vocabulary[47]. The purpose of the vocabulary is to provide a very simple mechanism for describing location information in RDF data. It aims at cross-domain RDF data mixing but not dealing with comprehensive issues tackled in the GIS domain. Spatially located entities can be described with latitudes and longitudes only in the WGS84 reference system. The vocabulary is limited to point features at this time and the vocabulary never became an official standard.

GeoRSS[48] was first released in 2006 and designed to extend the RSS (Really Simple Syndication)[49] for encoding geographic information in web feeds. GeoRSS serves as an informal extension to the Basic Geo vocabulary, adding more capabilities to describe locations (i.e. lines, polygons and boxes) other than points. There are two ways of encoding GeoRSS, which is GeoRSS-Simple and GeoRSS-GML. GeoRSS-Simple is designed as a very lightweight format so it can be easily added to the existing feeds. But the cost is that there is no direct upward compatibility with GML, and the only CRS supported is WGS84. However, users and developers with the needs to overcome these limits can turn to GeoRSS-GML that supports a greater range of features. Taking content directly copied from the GeoRSS original website, OGC published the GeoRSS Encoding Standard in 2017 (OpenGeospatialConsortium, 2017), making the community efforts standardised.

Another effort from W3C is the geospatial OWL/RDF vocabulary GeoOWL[50] published in 2007 by the W3C Geospatial Incubator Group (Geo XG). The GeoOWL vocabulary is an update of the previous W3C effort, i.e. Basic GEO vocabulary, to provide simple guidelines for presenting geospatial resources on the Web. The Incubator group recognises the works of OGC and ISO/TC 211, e.g. the General Feature Model, which are essential for the clarification of spatial representations in

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[47] https://www.w3.org/2003/01/geo/

[48] http://www.georss.org/

[49] https://en.wikipedia.org/wiki/RSS

[50] https://www.w3.org/2005/Incubator/geo/XGR-geo-20071023/

the GIS domain. But the breadth and depth of these works are beyond the needs of general web users. Therefore, the group adopted the GeoRSS feature model to develop the vocabulary instead of the OGC Simple Feature model. In essence, the GeoRSS model is consistent with ISO standards but different in emphasis providing a web-like feature view or aspect to existing content, which is more suitable for web resources in general. It allows descriptions of point, line, polygon and rectangle geometries of geospatial features in web resources. However, this vocabulary is not a W3C official recommendation and the basic model is not sufficient to represent the comprehensive issues in the GIS world.

NeoGeo Vocabulary (Norton et al., 2012) includes a Geometry Ontology[51] for presenting geography regions in RDF and Spatial Ontology[52] to describe topological relations. Geometry shapes can be represented by NeoGeo vocabulary including (multi-)Point, (multi-)LineString, (multi-)Polygon, LinearRing, Geometry Collection and Bounding Box. Each single point is recorded as an RDF resource and other geometric types are represented as an RDF collection, for example, a list of nodes which form a polygon is each represented as an RDF resource and the polygon is therefore the collection of those RDF resources. This methodology provides the vocabulary with maximum expressivity. If certain points are shared between regions, they would be easily identified, and consistency of each region can be retained if the shared border is updated. It also allows querying and reasoning relations upon these geometries. The vocabulary for describing topological relations is based on Region Connection Calculus (RCC) (Allen, 1981), capable of qualitative spatial representation and reasoning. The set of binary topological relations between spatial features are, for example, connects, equals and overlaps etc. NeoGeo vocabulary is based on a community effort stemming from 2009 aimed at providing a consensus RDF vocabulary with enough descriptive ability to meet the requirements for presenting geospatial data from various sources as Linked Data. However, this is an incomplete attempt and the vocabulary never became an official standard.

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[51] http://geovocab.org/geometry

[52] http://geovocab.org/spatial

The development of GeoSPARQL – A Geographic Query Language for RDF Data (Perry & Herring, 2012) started from 2009 by the GeoSPARQL Standard Working Group (SWG) and officially became an OGC standard in 2012. The aim of GeoSPARQL is to provide a unified representation for geospatial data in RDF and the capabilities for querying and filtering such geospatial data. The design of the vocabulary is not intended to be comprehensive but only a small set of top-level ontologies consistent with existing OGC standards such as Simple Feature model (Herring, 2011) and the GIS community is encouraged to develop additional vocabulary for describing spatial information on their own domains. In such a way, geospatial RDF from different sources can be communicated and cross referenced. The vocabulary includes a core set of high level RDFS/OWL classes for presenting spatial objects, a topology component which defines RDF properties for specifying topological relations between spatial features, and a geometry component containing RDF properties related to feature geometries, such as coordinate dimension that specifies the number of measurements for describing a geometry in a coordinate system (e.g. *geo*:*coordinateDimension*).

The query function part of the GeoSPARQL standard is extended based on the W3C SPARQL standard (Consortium, 2013), allowing queries on spatial features and their topological relations (e.g. geo:sfEqual), and providing functions for non-topological spatial analysis (e.g. geof:buffer). GeoSPARQL is designed to enable qualitative spatial reasoning and quantitative spatial reasoning on geospatial RDF data. The qualitative spatial reasoning system operates on spatial features that do not model explicit geometries. It asserts binary topological spatial relations between features. Different sets of topological relation families are supported other than the Simple Features relation family, that is, the Egenhofer relation (Max J Egenhofer, 1989) (e.g. geo:ehEquals) and the RCC8 relation (Allen, 1981) (e.g. geo:rcc8eq) families. Quantitative spatial reasoning systems on the other hand, operate on concrete geometries to perform computational evaluations, such as calculating distances. The two reasoning systems can interact with each other because a set of query transformation rules is defined based on W3C RIF rules (Boley et al., 2010) in the standard, allowing rewriting of feature-only queries in the qualitative reasoning system into geometry-based queries in the quantitative reasoning system. Conversely, the qualitative reasoning systems can draw conclusions from the results of quantitative reasoning because single query language is used for both types of reasonings (Battle & Kolas, 2012).

The implementation of GeoSPARQL is very flexible thanks to its modular design. Applications can choose to conform to selected requirement classes only based on its desired functionality levels. For example, implementing *core* and *topological vocabulary* components is sufficient for a pure qualitative spatial reasoning system (Perry & Herring, 2012). If an application wants to take advantage of the interaction between both quantitative reasoning and qualitative reasoning, the implementation will need to include all components with only one exception being the *RDFS Entailment Extension* component. All requirements classes and their dependency relations are shown in Figure 3.9.

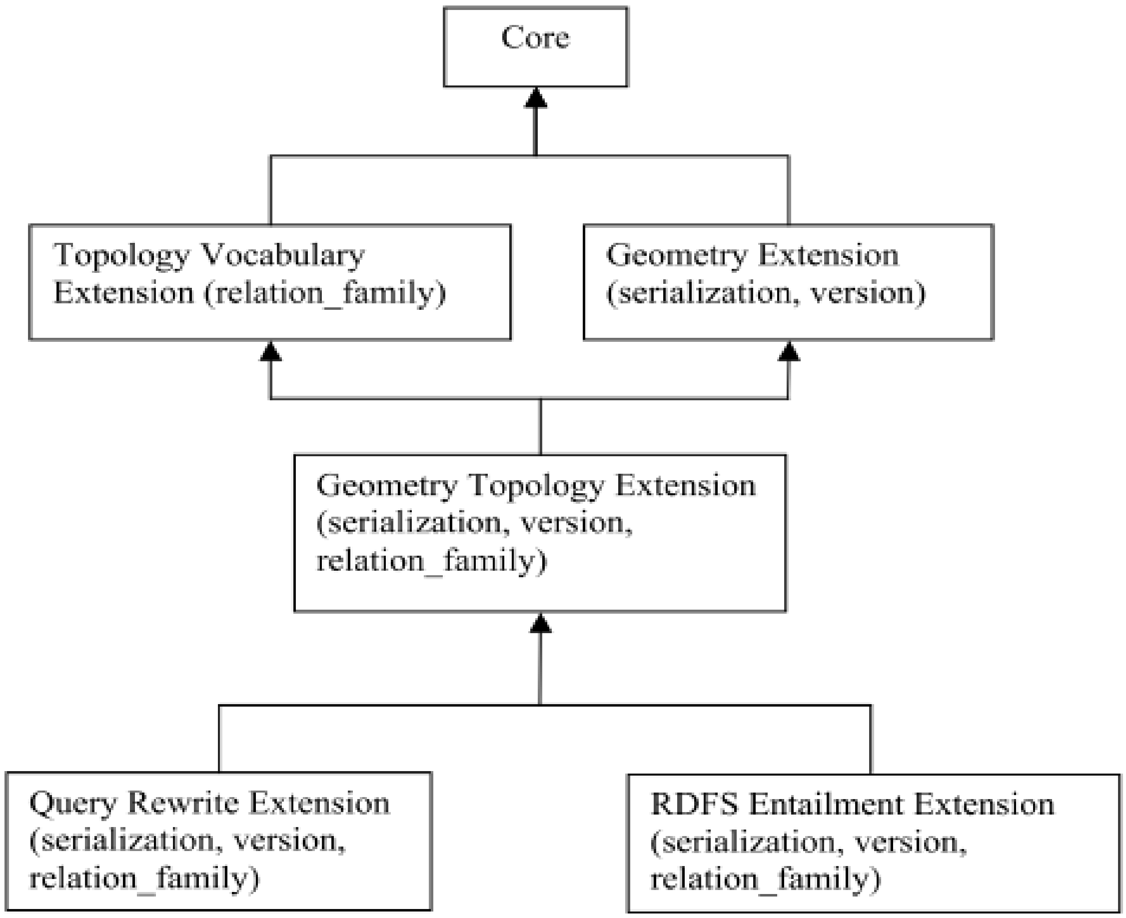

Figure 3.9 Requirements Class Dependency Graph (Perry & Herring, 2012)

The GeoSPARQL standard provides a unified presentation and data access method for geospatial data in RDF triple stores. By being compliant with the standard (either partially or fully), the majority of geospatial data should be able to be processed properly in the geospatial RDF stores and other domain data stored in the geospatial RDF stores can be properly indexed and queried as well, because the GeoSPARQL spatial ontology is intended to be used in combination with other domain ontologies. Furthermore, compliant triple stores enable geospatial RDF triples to be accessed and exchanged freely across platforms thus ensuring interoperability among different triple stores.

In conclusion, the available standardised geospatial vocabularies include GeoRSS and GeoSPARQL. GeoRSS is meant to be simple and used in encoding geospatial information in web feeds, hence it is not fit for encoding geospatial information for complex geospatial data analysis and process purposes. However, the development of GeoSPARQL is aiming at such purposes, i.e. to provide top level standard geospatial vocabularies that can be extend by different domains to represent geospatial data for various GIS applications to perform complex tasks, such as query, analysis and geoprocessing. Therefore, the study of geospatial RDF stores in the next section put lots of attention on whether a geospatial RDF store is compatible with GeoSPARQL standard and how strongly it supports the GeoSPARQL modules. Because the deployment of GeoSPARQL standard in geospatial RDF stores can greatly improve geospatial RDF triples' interoperability between storage systems in terms of semantic and querying perspective.

3.5.3 Geospatial RDF stores

The development of early geospatial RDF stores is to utilise the powerful combined features of both traditional DBMS and the RDF stores (Athanasiou et al., 2013; Battle & Kolas, 2012; Patroumpas, Giannopoulos, & Athanasiou, 2014). Traditional databases have long been proved to securely and reliably handle large volumes of data. Spatial-enabled RDBMSs are further equipped with spatial extensions for geospatial data processing and spatial queries. On the other hand, RDF stores are attractive because of the capabilities of handling complex queries, such as interlinking multiple features, querying variable properties and inferencing (ontological reasoning or rule-based reasoning). The typical implementation method is to extend additional geospatial functionalities to existing RDF frameworks and relies on the well-developed spatially enabled RDBMSs for the storing and querying of geometries (Ioannidis et al., 2019).

Early reviews of the geospatial triple stores conclude that not many triple stores support geospatial RDF data and even less fully conform to GeoSPARQL standard (Athanasiou et al., 2013; Garbis et al., 2013; Patroumpas, Giannopoulos, et al., 2014). The support of geometry types and coordinate reference systems is also very limited, i.e. most systems support points in WGS84 only. The performance of RDF stores is also less satisfactory compared to RDBMSs in terms of geospatial data management, such as storage, spatial indexing, scalability, data loading and query execution etc. Most reviewed geospatial triple stores at the time were Parliament, Strabon, uSeekM, Virtuoso and OWLIM etc.

Parliament[53] was released by Raytheon BBN Technologies (BBN) as an open source project in 2009. It originally supported geospatial data presented in the GeoOWL vocabulary and allowed querying on RCC8 and OGC Simple Feature relations. Later on, Battle and Kolas (2012) implemented GeoSPARQL specifications within Parliament based on the draft version. Parliament supports almost all GeoSPARQL components except the query rewrite component.

Strabon[54] is an open source spatial-temporal RDF store which can manage geospatial data change over time. The primary vocabulary and query language supported in Strabon for geospatial data is stRDF and stSPARQL (Kyzirakos, Karpathiotakis, & Koubarakis, 2012) which developed at about the same time as GeoSPARQL. stRDF is based on OGC standards Well Known Text (WKT) and Geography Markup Language (GML) to present geospatial data as literal data types. stSPARQL is extending SPARQL 1.1 with some functions from OGC standard "OpenGIS Simple Feature Access for SQL" for query and manipulate spatial features. stRDF/stSPARQL is regarded as very similar to GeoSPARQL in terms of presenting geometries as literal types and extending SPARQL functions for spatial analysis by mapping them with spatial predicates and functions. However, stSPARQL does not

[53] https://github.com/SemWebCentral/parliament

[54] http://www.strabon.di.uoa.gr/home.html

specify any binary topological relations to be used as RDF properties, therefore it does not have the capability for further spatial reasoning. These functionalities are supported by the topological extension and query rewrite extension part of the GeoSPARQL. So technically speaking, stSPARQL provides features equal to a subset of GeoSPARQL including the core, geometry extension and geometry topology extension. Therefore, it is easy for Strabon to also support these three components of the GeoSPARQL standard.

uSeekM[55] is one of the projects developed under the Open Sahara free web service that provides an extension library for RDF triple stores based on Sesame (now known as RDF4J). It enables indexing and querying functionalities to triple stores and can be integrated with other tools and frameworks. uSeekM is compliant with the GeoSPARQL standard including indexing, efficient search, computations on geometries integrated right into the SPARQL query language and support all OpenGIS Simple Features geometries and relations.

Parliament, Strabon and uSeekM are all open sources developed within academic research, they have not been actively developed by the communities. On the other hand, Openlink Virtuoso is a commercial application and has been continuing to be developed. And it is also released as an open source version. Virtuoso was well-known since it was used to manage geospatial RDF triples for the LinkedGeoData project (Stadler, Lehmann, Höffner, & Auer, 2012). At the time, geographical coordinates were presented as a special RDF typed literal with the type *virtrdf:Geometry* as geometry is regarded as an object value in an RDF triple. The geometry support in Virtuoso is only limited to point geometries in the WGS84 coordinate reference system. And there is no GeoSPARQL conformance within Virtuoso. As of Virtuoso 7.1[56] onward, it is enhanced with more geometry data type's support (including (multi-)point, (multi-)LineString, (multi-)polygon, polygon with hole and geometryCollection etc.) and a rich set of geometry functions for use in SQL and RDF geospatial queries. The full support for GeoSPARQL standard is also added through plugin *geos* which serves as an interface between the Virtuoso

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[55] https://www.openhub.net/p/useekm

[56] http://vos.openlinksw.com/owiki/wiki/VOS/VirtGeoSPARQLEnhancementDocs

engine and the *GEOS library*[57]. Similarly, plugin *proj4* supports the transformation between coordinate reference systems.

Besides Virtuoso, latest studies are in favour of open source/free Eclipse RDF4J, Apache GeoSPARQL-Jena, and Ontotext GraphDB (formerly known as OWLIM) as they are developed into more mature technology environments, with advanced performance, increasing support for geospatial data, and increasing compliance with the GeoSPARQL standard (Huang et al., 2019; Raza, 2019). Another observation in these studies is that cross-platform interoperability is also increasing as they are using the same syntaxes for geospatial queries with GeoSPARQL. Their capabilities of semantic reasoning including ontological reasoning (e.g. RDFS, OWL, OWL2 etc.) and rule-based (e.g. SWRL) are important features for these RDF stores.

RDF4J[58] (formerly known as Sesame) is an open source Java framework. It can be used as a standalone RDF store and provides parsing, storing, inferencing and querying over RDF data; as well as a library compatible with third party RDF stores (such as Strabon, Virtuoso etc.) allowing them to develop better scalability or extended features. RDF4J partially supports GeoSPARQL by using the well-known Spatial4J and JTS libraries on top of any RDF4J repository for geospatial reasoning. By default, it only supports GeoSPARQL functions on top of geospatial data that is presented as Well-Known Text (WKT) in WGS84.

GeoSPARQL-Jena[59] is an implementation of the GeoSPARQL 1.0 standard for SPARQL query or API based on the open source Java framework Apache. The support of GeoSPARQL is strong in which all six conformance classes defined in the standard are implemented; supports both WKT and GML serialisations; and supports all three spatial relation families. It also provides additional features such as automatic conversion between coordinate reference systems and automatically calculates geometry properties.

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[57] GEOS (Geometry Engine - Open Source) is a C++ port of the Topology Suite (JTS). As such, it aims to contain the complete functionality of JTS in C++. This includes all the GIS Simple Features for SQL spatial predicate functions and spatial operators, as well as specific JTS enhanced topology functions. https://www.osgeo.org/projects/geos/

[58] https://rdf4j.org/

[59] https://jena.apache.org/documentation/geosparql/

GraphDB[60] (former OWLIM) is a commercial product developed by the Ontotext vendor, but it also provides a free edition in addition to Standard and Enterprise version. It utilises the Knowledge Graph technology to provide a scalable and trustworthy storage solutions for RDF data. Entities (such as real-world objects, events, situations or abstract concepts) descriptions can be presented in GraphDB as an interlinked collection. These descriptions are formally structured allowing both humans and machines to process efficiently and unambiguously; and they contribute to one another where each entity is part of the description of the entities, forming a network that relates to each other. GraphDB fully supports SPARQL 1.1 therefore data can be queried via structured queries. It is compatible with the RDF4J framework and can be deployed anywhere using JAVA. It also has support for geospatial indexing and querying, plus strong GeoSPARQL compliance.

To sum up, the proposed AGDC system developed in this research relies on geospatial data to be presented in RDF triple format. And if RDF triples are presented based on GeoSPARQL standard then they can be queried on their topological relations and/or perform non-topological spatial analysis. It can be very useful if these query functions are incorporated into SWRL rules for automatic feature relationships inferencing and feature filtering. Therefore, in this research efforts have been put into studying the GeoSPARQL vocabulary, geospatial RDF conversion tools and triple stores around the utility of GeoSPARQL standard to develop the AGDC system.

However, although the importance and novelty of the GeoSPARQL standard is highly appreciated in this research, at the time of the development of the case study and proof of concept application for this research, the study and implementation of GeoSPARQL standard in the geospatial domain is still at an early stage, and there are limited studies (Battle & Kolas, 2011a, 2011b, 2012) and technical resources available regarding how to actually deploy the standard. Although great efforts have been attempted in this research to incorporate GeoSPARQL vocabularies with this research's ontologies and using GeoSPARQL functions in the SWRL rule chains, it

[60] https://www.ontotext.com/products/graphdb/

did not succeed. Apache-Jena and its spatial query syntax was used instead of earlier developed geospatial triple stores (i.e. Parliament, Strabon and uSeekme etc.) and GeoSPARQL query syntax deployed in the case study and proof of concept application.

Even though the reviewed geospatial triple stores were not able to be deployed in this research at the time of case study and proof of concept development, nonetheless the review informs the development and novelty of OGC GeoSPARQL standard in the geospatial domain, as well as the geospatial triple store development efforts around the GeoSPARQL standard. For example, one such effort is the GeoSPARQL-Jena which is the implementation of GeoSPARQL standard for Apache-Jena in more recent development. In future work, GeoSPARQL-Jena can be further looked into if it can replace Apache-Jena to be successfully implemented in the case study and the proof of concept geospatial data conflation system. In the case of success, the original idea of encoding geospatial data based on GeoSPARQL vocabularies together with custom ontologies and incorporating GeoSPARQL query functions and analysis functions into SWRL rules for automatic reasoning can be realised.

3. 6 Summary

This chapter aimed at justifying the necessity and benefits of using RDF as a common data interchange format for enabling automatic geospatial conflation. Presenting geospatial data in the RDF format facilitates effectively overcoming the geospatial data heterogeneous issues in three hierarchies, namely syntactic heterogeneous, schematic heterogeneous and semantic heterogeneous.

RDF is also advanced in interlinking and integrating data from different sources due to its simple and flexible data model. It is encouraging to see that in the past decade, both conversion tools for converting legacy geospatial data into geospatial RDF data and the relevant data management system, i.e. geospatial RDF stores, are increasingly mature and performances are improved. Importantly both conversion tools and RDF triple stores are trending to comply with the OGC GeoSPARQL standard. Therefore, enabling interoperability across platforms with geospatial RDF data allows them to meaningfully communicate with each other.

RDF is a foundation block in the Semantic Web Technologies Stack enabling upper level logic reference and rule-based reasoning. Geospatial data presented in RDF format will enable implicit knowledge to be inferred through explicit triples either through ontological reference or SWRL-based reasoning, thus realising the automatic conflation.

4 SEMANTICS THROUGH ONTOLOGIES

In chapter 3, the benefits and necessities of presenting heterogeneous geospatial data in RDF format was discussed. Converting source datasets into RDF format can help tackle data heterogeneity issues in syntactic, schematic and semantic levels. However, simply converting data into RDF format does not capture any semantic information (Vilches-Blázquez & Saavedra, 2019) as it relies on ontologies to be used at the same time to encode semantics for the RDF triples (Janowicz et al., 2010). While hierarchical interoperability issues have been simplified to the single RDF syntax, the issues regarding ontology design and their usages remain (Kuhn et al., 2014). This chapter reviews ontology-based data integration systems that exist in literature to understand the common structures and methods in designing ontologies. The chapter also explains the research approach to generating ontologies for automatic geospatial data conflation. Special attention is given to the OWL and Protégé as the tools to design ontologies for this research.

4. 1 Geospatial Ontology Architecture

4.1.1 Ontology-based Integration Systems

Ontologies have been long recognised as an effective way to overcome semantic heterogeneity issues when dealing with multiple sources of information integration. A survey done by Wache et al. (2001) analysed about 25 information integration systems that utilised ontologies in systems at various levels. The survey concluded that nearly all ontology-based integration systems studied were using ontologies for content explication, i.e. making implicit and hidden knowledge explicit. Another survey done by Natalya F. Noy (2004) pointed out that not only do ontologies provide a formal description of a domain of discourse; ontologies are also expected to be shared. Therefore, there is a desire to develop common top-level ontologies that can be extended by more specific domains and applications. Furthermore, the authors pointed out inference and reasoning are central to ontology-based integration approaches, as ontologies are intended to be developed for use with reasoning engines.

In the geospatial domain, semantic interoperability has been studied since the 1990s as a mean to overcome data heterogeneous barriers (Bishr, 1998) that stand in the way of GIS interoperability (Frederico Fonseca & Egenhofer, 1999; Frederico

Fonseca et al., 2002), to achieve geospatial data sharing (Harvey, Kuhn, Pundt, Bishr, & Riedemann, 1999), and to effectively integrate geospatial datasets (Frederico Fonseca, Egenhofer, Davis, & Câmara, 2002; Uitermark et al., 1999). The research of Frederico Fonseca and Egenhofer (1999) focused on developing an ontology-driven geographic information system (ODGIS), which uses an ontology and translates it into the system as an active component for the user to use. Frederico Fonseca et al. (2002) stressed that a consensus top level ontology shared by a geospatial information community must be developed before the ODGIS developments, because it serves as the foundation of systems interoperability as each ODGIS has to adapt the information stored in its database to fill in the classes of the ontology.

The concept of a geospatial information community is defined as a group of spatial data producers and users that share formal ontologies corresponding to real-world phenomena, and the ontologies being shared is a particular knowledge base that describes facts always true for the community (Frederico Fonseca et al., 2002). A community developed ontology for ODGIS can develop at different levels with the top-level ontology being the first one, and then more specific ontologies based on the entities and basic concepts developed at the top-level ontology can be further detailed and can be presented with new combinations.

4.1.2 Hierarchical Ontology Structure

The hierarchical structure of ontology development is elaborated in the work of Frederico Fonseca et al. (2002) as a new way to realise different levels of detail in geographic information integration. The hierarchy is classified as four layers: 1) Top-level ontologies describe very general concepts; 2) Domain ontologies define specific domain vocabularies; 3) Task ontologies specify a task or activity; and 4) Application ontologies generate concepts based on the combination of a particular domain and a specific task. In a nutshell, their approach is to link ontologies to geographic information sources through a semantic mediator. Therefore, when multiple ontologies are integrated, it will lead to geographic information integration.

Ontologies integration comes in two different ways, i.e. vertical integration and horizontal integration. Vertical integration works within a community that takes advantage of the *inheritance* feature during the hierarchical ontology development process being the creation of a lower level ontology always based on a higher-level ontology. Therefore, the low-level ontologies incorporate the knowledge they inherit from the immediate higher level refined with more details. On the other hand, horizontal integration targets integrating entities existing in multiple communities at the same time.

An earlier study by Uitermark et al. (1999), which focused on ontology-based geographic data integration claimed their proposed conceptual framework was the first of its kind. Their conceptual framework is shown in Figure 4.1. While general geographic information integration aims for semantic interoperability and sharing of information between different sources produced from various communities, this study has a more specific purpose in mind. That is, in the context of update propagation, which means the datasets are within a particular domain and corresponding objects in the involved datasets are more closely related other than those in generic purpose integration.

The essence of the approach for data integration is to identify the semantic similarity between corresponding geographic object instances from independently produced sources (see Figure 4.1, the first two levels from the top of the framework). To achieve the goal, first the domain ontology (the second level from the bottom of the framework in Figure 4.1) for a specific discipline is defined (e.g. topographic mapping in this study). It includes a collection of concepts commonly accepted in the domain of interest, formally and explicitly defined through a certain ontology language (e.g. Prolog in this case).

Next, an application ontology is constructed for every dataset used in the integration process because the concepts' meaning in each dataset is not always the same as those concepts in the domain ontology that have similar names. Therefore, the third component of the approach is required, i.e. abstraction rules, which specify the relationships between concepts in the domain ontology and the concepts from the application ontologies. For example, if concepts from different application ontologies all refer to the same concepts in the domain ontology, then they are semantically similar. Therefore, corresponding object instances can be subsequently defined as semantically similar. Abstraction rules also include other instructions about what and how feature objects should be captured as well.

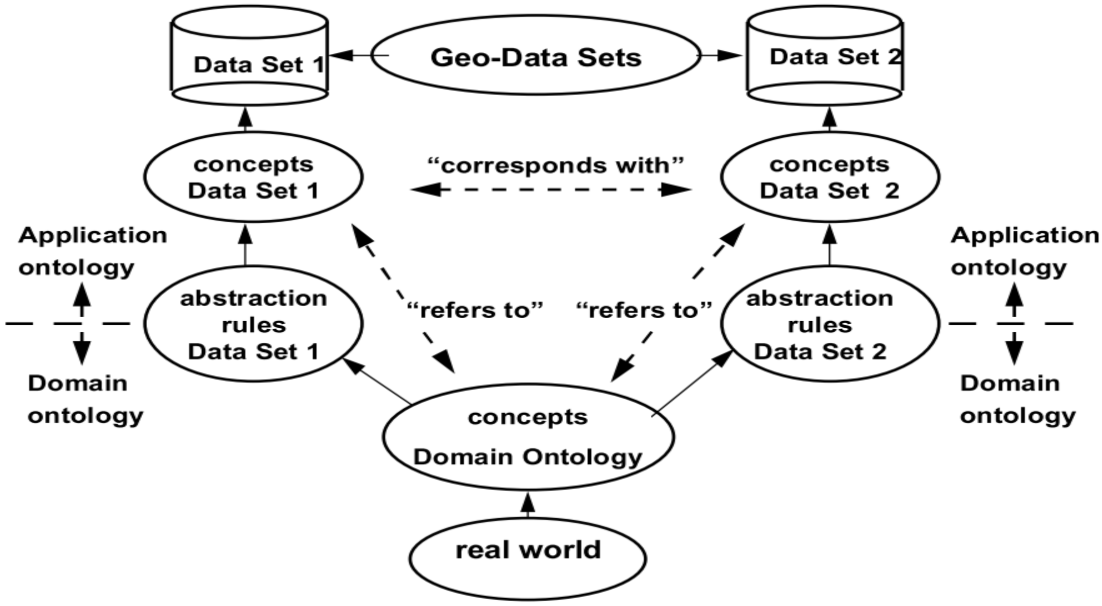

Figure 4.1 Ontology-Based Geographic Data Integration Framework (Uitermark et al., 1999)

In more recent studies, which are aimed at data integration in a distributed Geospatial Web environment, an architecture of ontologies is proposed to include five distinct types of ontologies to build a semantic layer for the existing Geospatial Web that can be augmented and enriched by the geospatial semantics (Kolas et al., 2006; Kolas, Hebeler, & Dean, 2005). By leveraging the existing standardisation efforts in the geospatial communities, especially OGC standards such as GML and WFS, the proposed ontology architecture includes:

(a) Base Geospatial Ontology which is the core vocabulary and structure for presenting geospatial knowledge which all other types of ontologies must refer to and should be standardised;
(b) Domain Ontology that contains knowledge presentation aligned with a specific domain or type of user;
(c) Geospatial Service Ontology that conforms to the OWL-S (Martin et al., 2004) specification, and additionally add in ontological definition of geospatial concepts that are not in the scope of OWL-S, thus enabling automatic discovery, invocation and composition of Geospatial Semantic Web services;

(d) Geospatial Filter Ontology that defines vocabulary and rules for geospatial decomposition and filtering, adding capabilities to distribute a complex query across multiple Semantic Web services;
(e) Feature Data Source Ontology that targets geospatial services offered via WFS by providing an ontological view of what type of data will be returned.

Kolas et al. (2006) advocate ontology standardization efforts within the geospatial community, for example, in addition to the Base Geospatial Ontology, the standardization of Filter Ontology for handling spatial relationships are proposed and a potential standard set of SWRL rules to imply geospatial relations by developing geospatial SWRL built-ins are also mentioned. This recommendation has been met partially. For example, the OGC standard GeoSPARQL (Perry & Herring, 2012), published in 2012, provides a core ontology for unified representation of geospatial data in RDF, specified constructs for presenting topological relations between spatial features and the capabilities to query and filter geospatial data stored in triple stores.

The ontology architectures in the above-mentioned research are varied because specific application purposes are different. However, their approaches to generating ontologies are similar in general. Both the ODGIS (Frederico Fonseca & Egenhofer, 1999; Frederico Fonseca et al., 2002; Frederico Fonseca et al., 2002) and the Geospatial Semantic Web ontology architecture (Kolas et al., 2006; Kolas et al., 2005) include a top-level ontology to enable a wider range geospatial data interoperability and data integration. *Geospatial Service Ontology*, *Geospatial Filter Ontology* and *Feature Data Source Ontology* are designed to fulfil data integration requirements in distributed web environments (Kolas et al., 2006; Kolas et al., 2005), fall into the categories of *Task Ontology* and *Application Ontology* defined in the ODGIS (Frederico Fonseca & Egenhofer, 1999; Frederico Fonseca et al., 2002; Frederico Fonseca et al., 2002). The conceptual framework proposed by Uitermark et al. (1999) mainly includes *Domain Ontology* and *Application Ontology* as it is targeting less human intervention during the data update process, which involves datasets only within a particular domain. In summary, a domain ontology is an essential part of ontology architectures in the reviewed research regardless of their intended application purposes.

In this research, domain ontology is regarded as an essential part of the ontology structures as it provides a common ground for sematic exchange and understanding among multiple source datasets involved in the conflation process. And the development of a domain ontology for geospatial data conflation is based on a standard data model widely accepted within a domain where the similar point of view has already existed. In the next section, attention will be focused on the standard data model in the Australian geospatial industry and the ontology development efforts within Australia.

4. 2 Geospatial Standard Data Model and Ontology Development in Australia

4.2.1 National Foundation Geospatial Data for Australia

The Foundation Spatial Data Framework (FSDF)[61] is a prominent national standardisation effort in Australian SDI. An initiative sponsored by ANZLIC[62], the FSDF aims at providing a common reference for the assembly and maintenance of foundation level spatial data for Australia and New Zealand. The FSDF identifies and groups Australian wide geospatial data into ten different themes (see Figure 4.2) of national coverage foundation geospatial data that are best available, most current, and the authoritative sources which are standardised and quality controlled.

Figure 4.2 FSDF Data Themes (ANZLIC, 2020)

[61] http://fsdf.org.au/

[62] ANZLIC – the Spatial Information Council is the peak intergovernmental organisation providing leadership in the collection, management and use of spatial information in Australia and New Zealand. https://www.anzlic.gov.au/anzlic-council

For example, the Place Names theme contains foundation datasets recording location and extent relevant to place names; names are either linked to physical features or cultural/historical features. Such datasets include state or territory aggregated gazetteer place name datasets (e.g. Points of Interest and Geographic Names). Figure 4.3 is a current snapshot of identified priority datasets for the Place Name theme, where datasets maintained at state and territory government levels, as well as commonwealth level), and the nationwide Gazetteer of Australia aggregated by Geoscience Australia sourced from states and territories. Place Names theme datasets are central to many services, such as emergency responses who rely on authoritative, accurate place names and their location to effectively save lives and properties. The general public uses Place Names theme datasets in their daily activities, such as for navigation and tourism etc.

The development of national coverage foundation datasets faced many technical as well as social challenges as the production and management of geospatial data are fragmented and heterogeneous across multiple government levels. An alignment study by Van der Vlugt (2012) conducted by the Cooperative Research Centre for Spatial Information (CRCSI) investigated the Spatial Data Supply Chain (SDSC) management situation in Australia and New Zealand. The capability of maintaining automatic, flexible and distributed end-to-end SDSC management was regarded as one of the key technology enablers of SDI and is also seen as important for effectively supporting the emerging Australian and New Zealand Spatial Marketplace (ANZSM). The study by Van der Vlugt, surveyed 34 SDSC projects in Australia and New Zealand, which are almost exclusively government driven, and concluded that there is little to no coordination between all levels of jurisdictions. Agencies and organisations have very limited understanding of what components have already been built and what data are available. There is inevitably existing duplicate or overlapping geospatial data. Therefore, it is particularly challenging when integrating those patchy source datasets developed by all levels of government agencies under their respective business context into a coherent suite of interoperable national products where data structures and semantics are very different. The Data Specification Framework for the FSDF (Box et al., 2015) aims at addressing these challenges and is developed to refine existing datasets and produce new national foundation products.

Figure 4.3 Snapshot of current identified Place Names Theme dataset[63]

4.2.2 Data Specification Framework for the Foundation Spatial Data Framework

The FSDF data specification framework consists of three components that are relevant to each other. Their relationships are shown in the FSDF model framework overview, see Figure 4.4. The Modelling and Model Management components which are shown on the left-hand side of the diagram contains the description of the modelling tools, processes and actors from a high-level perspective. The components define key stakeholders as different actors because they are playing different parts in the modelling process. Modellers are those who develop, examine and (re)use FSDF models, which can be further divided into whether they are FSDF product modellers,

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[63] https://link.fsdf.org.au/dataset/national-gazetteer-australia

theme modellers or core FSDF modellers. Other actor roles include FSDF data product developer and product user where the former one develops foundation data products for end users by implementing FSDF product models, and the latter one is the end user who uses the FSDF products and associated documents but also provides use cases and requirements that form the basis of the development and evolution of foundation data products. Putting all these actor roles together, they are in fact modelling the entire supply chain from conceptual models' development to the foundation data production, and future development which is considering the future needs of users to refine the supply chain. Individual organisations involved in the FSDF supply chain now know which role they play and are also aware of other parts along the supply chain leading to clearer and better communications between parties, a reduction in data duplication, as well as improving efficiency along the supply chain.

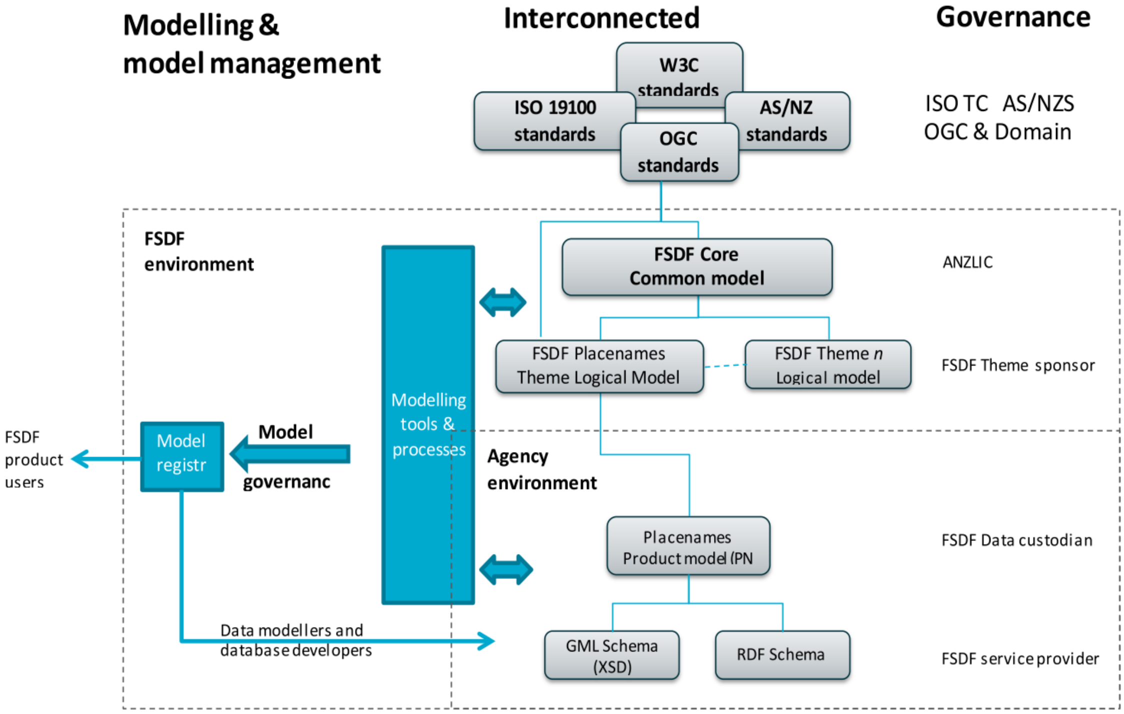

Figure 4.4 Overview of the FSDF model framework (Box et al., 2015)

The Governance component which is shown on the right-hand side of the diagram describes the governance of the FSDF models and vocabularies from their creation, publication, use and retirement. Both FSDF models and vocabularies are implemented as a federated governance model. For instance, ANZLIC as the FSDF peak body, has the overall authority and responsibility for core common models; while FSDF theme sponsors take ownership of theme models, and the FSDF product custodians have responsibility for maintaining data product models. Such a governance method is effective and accountable, it enables the governance of modular interrelated models and avoids an individual organisation being overloaded. Furthermore, it assures flexible and sustainable management of model changes because data models are not static but constantly changing due to exploiting emerging technology paradigms and improving products that meet new requirements.

The core component of the FSDF data specification is a suite of modular and independent models, as shown in the middle of the diagram, which are the most relevant component to this research. As discussed in previous chapters, geospatial data heterogeneity happens at syntactic, schematic and semantic levels. While syntactic heterogeneity issues have been well addressed by implementing standard exchange methods, such as OGC standards, schematic and semantic heterogeneous issues are still ongoing research topics.

The geospatial data heterogeneity issues occur due to the same real-world object (for example, streets or buildings) being captured and represented for various purposes with different points of views (a.k.a conceptual schemas). Even geospatial data products created from the same view are various between different organisations because data structures, attributes and classification schemes are implemented differently (for example, POI data are collected differently by various agencies). Putting it into the FSDF context, different points of view datasets are classified into different themes and the same point of view datasets are grouped into the same theme. The development of the suite of modular and hierarchical FSDF models is intended to achieve interoperability between FSDF foundational datasets within each theme as well as across the entire FSDF.

4.2.3 Standard Based FSDF Data Model Suite

The development of the FSDF models is implemented using a standards-based modelling methodology. The ISO 19100 standard series are primarily used as they are the conceptual framework from which different theme information models can be developed consistently to form the FSDF data specification. The FSDS data specification can then act as a standard for developing data products and exchanging data from different providers. OGC standards are also incorporated in the modelling processes as the objective of delivery interoperable foundation data products are primarily through web services although not exclusively. Other standards are used in the modelling process including Australia and New Zealand national standards and the increasing popular W3C standards as well. The FSDF models developed by using these standards provide constructions for foundation datasets to be produced and delivered in a standardised and interoperable manner. Foundation data interoperability is not only fully achievable within each theme but also achieved to some extent across different themes, therefore improving coherence for the entire FSDF. Furthermore, foundation data interoperability with other geospatial data can be met to some extent outside the scope of FSDF if other parts of the spatial information community adopt ISO, OGC and W3C standards to develop their own products. The adoption of standards by data providers will decrease the efforts required for users to integrate multiple source datasets to meet application needs.

The intention of the development of the data specification framework goes beyond supporting the development of national foundation spatial data products and encouraging broader engagements such as other non-spatial government data initiatives to realise its best interests and benefits. The modelling processes of the FSDF is critical in resolving multiple datasets from different government organisations with different formats, structures and semantics and producing national consistent products by transforming them into a common structure with common meanings. The modelling is critical in developing national foundation data, but it can also be utilised in parallel for developing state and territory level data. The investment value increases as more related data products are developed using FSDF models. Therefore, the geospatial data conflation research reusing the FSDF standard models as fit-for-purpose output data models whenever possible is compliant with the national data standardization effort in a cost-effective way. However, the availability of the FSDF models from different themes varies, so the utilisation of the FSDF models need to be analysed on a case by case basis.

The FSDF models are available at several levels with the Common Conceptual Model sitting at the top, from which a Thematic Model is developed for each theme and separate Product Models are included for each foundation product within the theme. The Common Conceptual Model specifies concepts, relationships and patterns that are commonly required across all themes which enables data coherence across the entire FSDF. For example, defining the coordinate reference systems (CRS) and temporal reference systems to be used for all themes, or the patterns to be employed for assigning unique object identifiers etc.

Thematic Models include Thematic Conceptual Models, Thematic Logical Models and Thematic Product Models. Similar to the Common Conceptual Model, the Thematic Conceptual Model also defines commonly accepted concepts, relationships and patterns but limited to a FSDF theme. The Thematic Logical Model is the lowest level of common grounding where existing product models are embraced. Existing product models are compared and use case requirements are addressed when developing thematic logical models. Concepts and their relationships are refined, properties and data types are specified into the thematic logical models and then tested against the thematic conceptual model to make sure it’s compliant.

A Thematic Product Model is a specialisation of the Thematic Logical Model, either implementing part of the logical model or the whole. It describes foundation data products that are defined in a specific implementation platform. The modelling process is an ongoing process. By the time the FSDF specification framework was published, only Administrative Boundary Theme and Place Names Theme logical models were developed. The product model developed for the Administrative Boundary theme is a ‘to be’ model reflecting the future needs for this product theme, while the Place Names theme had developed a national gazetteer product (as is) model that documents the current state of Place Names data theme.

In the real world, data models and relevant data products are developed within organisations to meet their business needs. It is unrealistic to prevent this from happening but instead the FSDF specification requires the models to be mapped to the FSDF models at some stage along the product evolution process. In this research, geospatial data conflation intended for conflating data sources from multiple government agencies into a single dataset by removing duplication, resolving data conflicts and improving accuracy is no doubt a data evolution process. Mapping conflation output data models to a FSDF model or using a FSDF model directly (if it is fit for purpose) as a conflation output model is a good practice for building authoritative and single point of truth data for Australia SDI.

4.2.4 FSDF Controlled Vocabulary and Australia Geospatial Ontology Development

FSDF controlled vocabularies are developed as part of the core component of the FSDF data specification, which together with the suite of models, define foundational data and how it is used. Controlled vocabularies are normally defined or referenced within models. However, in order to reflect on the emerging best practice and governance realities, controlled vocabularies are separated from models and placed as online resources to promote reuse between models. The FSDF data specification framework has recommended storing the FSDF controlled vocabularies through online registers - accessed through online services. Such governance and reuse of the FSDF controlled vocabularies are not only critical to ensure interoperability between foundation products within the FSDF but also enable interoperability beyond FSDF with other data initiatives, for example, data.gov.au.

The FSDF models are defined using the formal Unified Modelling Language (UML) where modelling processes typically focus on database design and assessment of completeness and validity. Controlled vocabularies are identified through the modelling process and used to facilitate information communication for models. Publishing FSDF model ontologies online once registered with a model register is one of the recommendations from the FSDF data specification framework. Ontologies can be used together with data to infer additional information because they are both human and machine readable.

The first government linked open data was developed by Taylor et al. (2014) which also developed an ontology for the project by extending several popular community ontologies. This project has subsequently stimulated the establishment of an

Australian Government Linked Data Working Group (AGLDW)[64] which aims to develop technical guidelines and best practice advice for Australian government linked data practices. The group is also building an ontology for Australian Government data. Currently, the development of standard ontologies fit for Australia usage is still at an early stage and continuous efforts required to develop nation-wide geospatial standard ontologies.

This research believes the method of developing ontologies from standard FSDF models would benefit from the standardised efforts of FSDF and in turn have the potential to make the ontologies created standardised. Therefore, it can contribute to the Australian standard ontology's development practices.

4. 3 Ontology Generation for Geospatial Data Conflation

4.3.1 Define Ontologies Based on Output Data Model

The geospatial data conflation in this research is targeting duplicate geospatial datasets across Australian government agencies and aiming at the removal of duplicates thus improving accuracy along the Spatial Data Supply Chain (SDSC). The input datasets involved in the conflation processes are expected to be mainly from the same data producer/user community or same data theme, with a similar point of view (semantically similar). Therefore, a similar approach to the ontology structure presented by Uitermark et al. (1999) was applied in this research. The intended ontology structure in this research will mainly include a domain ontology and an application ontology.

The proposed Geospatial Data Conflation Conceptual model for this research is presented in Figure 4.5. In the conceptual model, the geospatial data conflation process for this research is defined into five stages. Stage 1 is generating ontologies for this research, then Stage 2 is converting source geospatial datasets into RDF triples based on the generated ontologies. After that, the data conflation system can perform its Stage 3 and Stage 4 process where SWRL rules are defined to perform Data Filtering and Data Reasoning to realise the conflation goal.

[64] https://www.linked.data.gov.au/

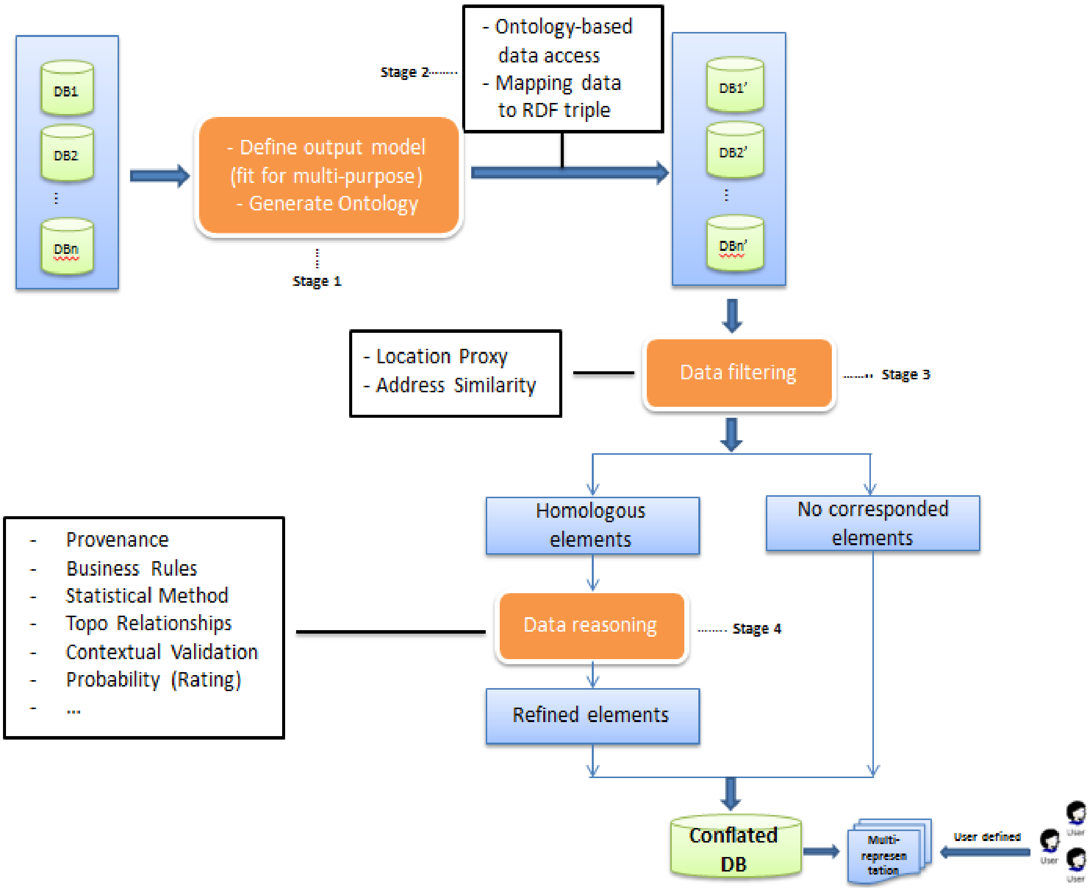

Figure 4.5 Data Conflation Conceptual Model

In Stage1 of the process, preliminary analysis of heterogeneous source datasets and different user needs are needed to be considered to formulate the output data model required to meet the business needs from the source agencies. Ontologies are then generated accordingly. However, this research is not planning to define a completely new model from scratch; instead, the research will use existing models whenever possible. Hence, it is important to investigate appropriate geospatial data models available in Australia and these are presented in Section 4. 2 to make use of the decades of standardization efforts within the Australian SDI.

The use of standards in the free market tends to be difficult because the market is in favour of unique ideas and products (Frederico Fonseca et al., 2002). However, government agencies are generally more favourable in collecting data in standard ways and some of the government agencies are standards publishers. Therefore, if agencies' source datasets are compliant with a certain national standard data model, their data interoperability can be assured (Box et al., 2015), and the generated ontology based on the standard data model can be used as the domain ontology. Such domain ontologies will also be able to be easily incorporated into a high-level ontology (specifically GeoSPARQL vocabulary) if required.

4.3.2 Developing Ontologies Using Web Ontology Language

OWL is an W3C standard first published in 2004 and currently in its second generation (OWL2) (Hitzler, Krötzsch, Parsia, Patel-Schneider, & Rudolph, 2009). It can be used to facilitate formal presentation of ontologies, so not only humans can understand what, but also machines. OWL is developed as an ontology language for the Semantic Web to exchange web content with greater expressiveness than XML, RDF and RDFS as it provides an additional vocabulary together with formal semantics. OWL has three sublanguages that increase in expressiveness, i.e. OWL Lite has the lightest expressiveness, OWL DL offers complete expressiveness and is still decidable, while OWL Full has maximal expressiveness but cannot offer computational guarantee. OWL DL is the most widely used version.

OWL is part of the technology stack that facilitates progressing toward the future Semantic Web vision, i.e. contents of the Semantic Web have explicit meanings and machines can automatically access and integrate such content information. OWL goes beyond the basic semantics of RDF Schema to describe meanings for Web contents and are presented in the flexible RDF structure (McGuinness & Van Harmelen, 2004). One advantage of OWL ontologies is that generic reasoners, based on the formal properties of the OWL language, can reason about them, thus reducing efforts to build domain specific reasoning systems that are needed in the case of using industry-standard XML schema (Welty, McGuinness, & Smith, 2004).

While OWL ontologies can be used along with information written in RDF to explicitly describe RDF semantics; OWL ontologies themselves are stored and exchanged primarily as RDF documents (Consortium, 2012). In addition, inference rules (such as SWRL rules) can also be stored as RDF triples. An example can be seen from Figure 4.6 which is a snapshot from the OWL ontologies developed for the case study in this research. The Data Instance part showing a data instance (marked in red) *POL_12283* with a list of data properties (*latitude*, *longitude*…) and object properties (*hasPOIClass*, *hasPOISubtype* etc.). The Ontology part defines a

PointsOfInterest class with a definition and its equivalent class (marked with purple). In the Rule section, it starts with some description about the SWRL variables followed by the SWRL body, etc. Having the data, ontologies and rules all in RDF means all information can be imported into reasoner tools at the same time for holistic information inferencing and processing. It is a strength that reasoners could even discover information that a human would not have realised.

```xml
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_12283 -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_12283">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <latitude rdf:datatype="&xsd;decimal">-32.05144316</latitude>
    <longitude rdf:datatype="&xsd;decimal">115.7497759</longitude>
    <houseNum rdf:datatype="&xsd;string">39</houseNum>
    <roadName rdf:datatype="&xsd;string">ADELAIDE</roadName>
    <locality rdf:datatype="&xsd;string">FREMANTLE</locality>
    <name rdf:datatype="&xsd;string">FREMANTLE WINE CELLARS AND PROVIDORES</name>
    <numType rdf:datatype="&xsd;string">H</numType>
    <roadType rdf:datatype="&xsd;string">ST</roadType>
    <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI"/>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Liquor"/>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
</owl:NamedIndividual>
```

Data Instance

```xml
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest">
    <rdfs:label xml:lang="en">PointsOfInterest</rdfs:label>
    <owl:equivalentClass>
        <owl:Restriction>
            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass"/>
            <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        </owl:Restriction>
    </owl:equivalentClass>
    <rdfs:subClassOf rdf:resource="&owl;Thing"/>
    <rdfs:comment xml:lang="en">Definition: Any place, feature or service that people wish to visit or know the location of, and is of value to the community. (WALIS) </rdfs:comment>
</owl:Class>
```

Ontology

```xml
<rdf:Description rdf:about="urn:swrl#p">
    <rdf:type rdf:resource="&swrl;Variable"/>
</rdf:Description>
<rdf:Description rdf:about="urn:swrl#str">
    <rdf:type rdf:resource="&swrl;Variable"/>
</rdf:Description>
<rdf:Description rdf:about="urn:swrl#string1">
    <rdf:type rdf:resource="&swrl;Variable"/>
</rdf:Description>
…
…
<rdf:Description rdf:about="urn:swrl#class">
    <rdf:type rdf:resource="&swrl;Variable"/>
</rdf:Description>
…
<rdf:Description>
    <rdf:type rdf:resource="&swrl;Imp"/>
    <swrl:body>
…
```

Rule

Figure 4.6 Data Instance, Ontology and Rule examples in RDF format

4.3.3 Direct Mapping of Data Model to Domain Ontology

The generation of ontologies in this research applies a top-down approach that means first creating the domain ontology from the appropriate data model to present the generic classes, properties and relationships for the interested domain. Then the domain ontologies are extended to cater for specific application needs, such as additional properties to enable mappings between ontologies and data schema elements, rules for inference relationships required by the application etc.

For example, in Figure 4.3, one of the identified foundation datasets within the FSDF 'Place Name' theme is the *WA Topographic: Points of Interest* dataset. In this research, the case study is to conflate various Point of Interest (POI) datasets from WA, hence the data model of *WA Topographic: Points of Interest* is an appropriate starting point for generating domain ontologies. A portion of the WA POI data model is presented in Figure 4.7. Each POI complies with a three-level hierarchy classification with red, blue and grey rectangles representing feature class, subtype and domain value, respectively. A two-digit number following each hierarchy level value is the class code, subtype code and domain code respectively. Also, each of the POIs will have some main attributes commonly captured by each agency but may present differently based on various business needs (e.g. name, address and coordinates within the green rectangle).

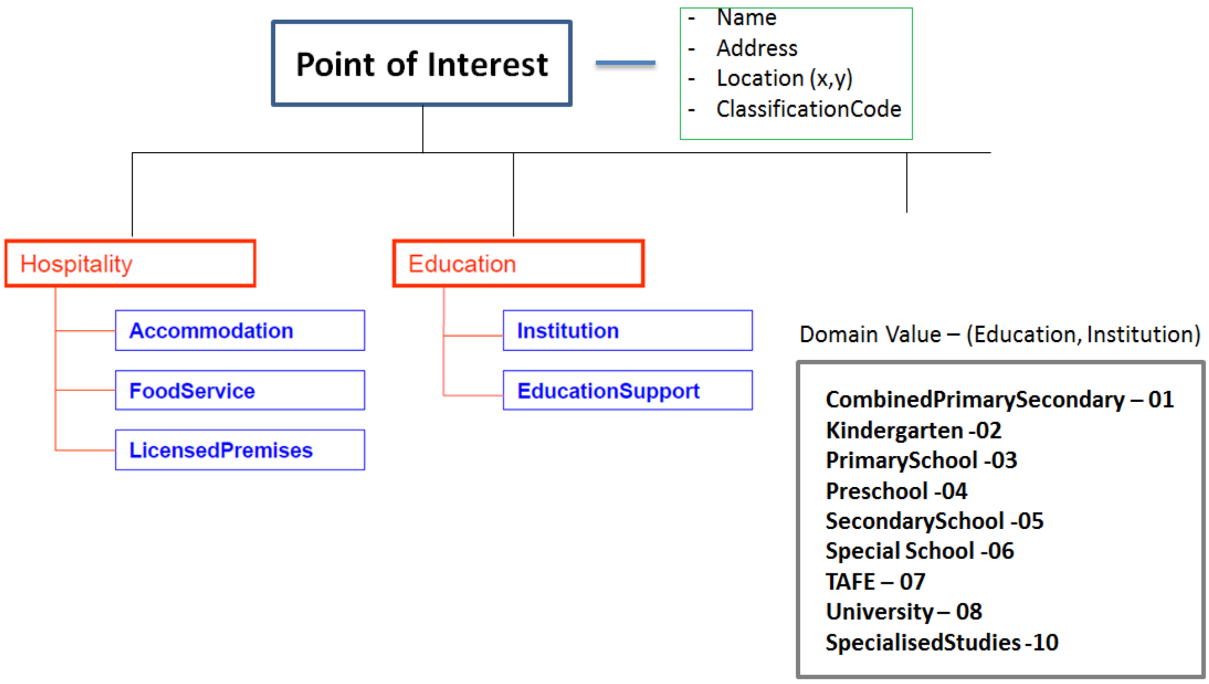

Figure 4.7 Points of Interest Data Model

The designed ontology structure is shown in Figure 4.8 where the left part within the red rectangle corresponds to the common three-level hierarchy classification model for POI. The rest of the ontology structure may be designed variedly for the attributes within the green rectangle of Figure 4.7 according to different application requirements. In summary, the ontology generation starts from the data model, which acts as a global schema and then can be expanded to accommodate various sources of datasets.

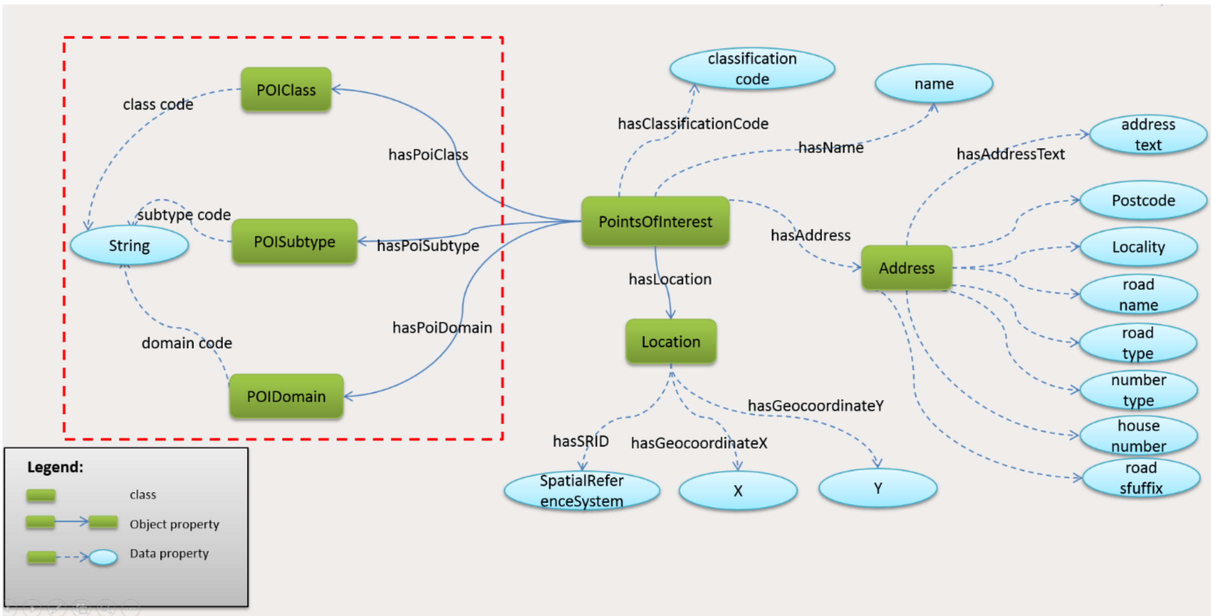

Figure 4.8 Generated POI Ontology based on the POI data model

4.3.4 Ontology-based Data Access

A data integration tool named Karma[65] is used to demonstrate how to build up the mappings between ontology and source data. Karma provides a graphical user interface that allows users to easily import the user's choice of ontology model and source data into the system (Gupta et al., 2012; Craig A. Knoblock et al., 2012). Then users can interactively map data to ontology classes. An example of mapping between data source schema and the ontologies is displayed in Figure 4.9. Within the orange box, is the original data which is in spreadsheet format. Each row represents a POI and each column presents a POI attribute. Inside the green box are ontologies that have been generated. It shows the relationships between ontologies and also how

[65] https://usc-isi-i2.github.io/karma/

they relate to each attribute in the source data. After successfully building the mappings between source data and ontology model, users can then choose to publish the data as RDF or store it a database for further use.

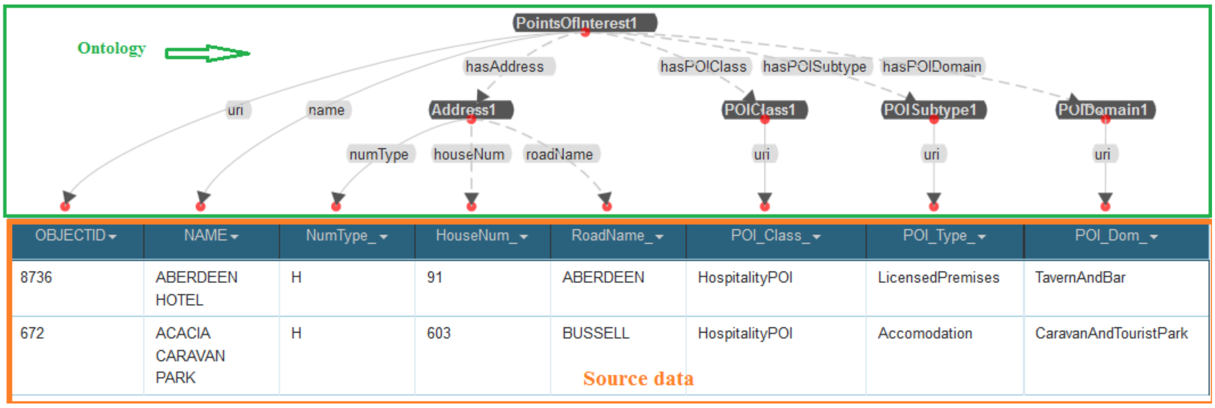

Figure 4.9 Example of mapping source data with generated ontology

4.3.5 An Open Source Ontology Editor – Protégé

Protégé[66] is a free, open source ontology editor and framework for building intelligent systems. It is based on Java, which is highly flexible and extensible for prototyping and developing customised applications. It also provides full W3C recommendations implementation support including the latest OWL 2 web ontology language and RDF specifications. The Protégé project dates back to the 1980s and its original aim focuses on building knowledge-based systems at the time (Musen, 1989). With years of development, Protégé gradually shifted into an open-source platform used for the development of ontologies (Natalya F Noy et al., 2001) and incorporated with OWL support since 2004 (Knublauch, Fergerson, Noy, & Musen, 2004). Protégé has now become the most widely used application for the generation and management of ontologies (Musen, 2015).

There are two types of Protégé systems available. One is a web-based system (WebProtégé) that provides collaboration opportunities for users to share and edit ontologies online. The second is the desktop version of Protégé which is currently at version 5 (Protégé 5) and offers many advanced functionalities to facilitate building

[66] https://protege.stanford.edu/

and managing OWL ontologies. The desktop version of Protégé is adopted in this research as the online collaborative sharing and editing function is not required.

The Protégé user interface consists of a series of tabs (such as Classes, Object properties, Data properties and SPARQL Query etc.). Each tab contains different views to meet specific ontology design needs, see Figure 4.10 as an example. If required, existing ontologies and/or standardised ontologies can be used in conjunction with the developing ontologies by directly importing the existing ontologies (see the green highlighted part on Figure 4.10). A list of used ontology namespaces and their prefixes can be defined in the Ontology Prefixes tab, see the blue rectangle part as an example (Figure 4.10).

The vast variety of view options and the flexibility of their arrangement on screen within the Protégé user interface, provides a great user experience for ontology designers. Being able to import existing ontologies as well as the ability to create SWRL rules fulfils all the functionality requirements for this research.

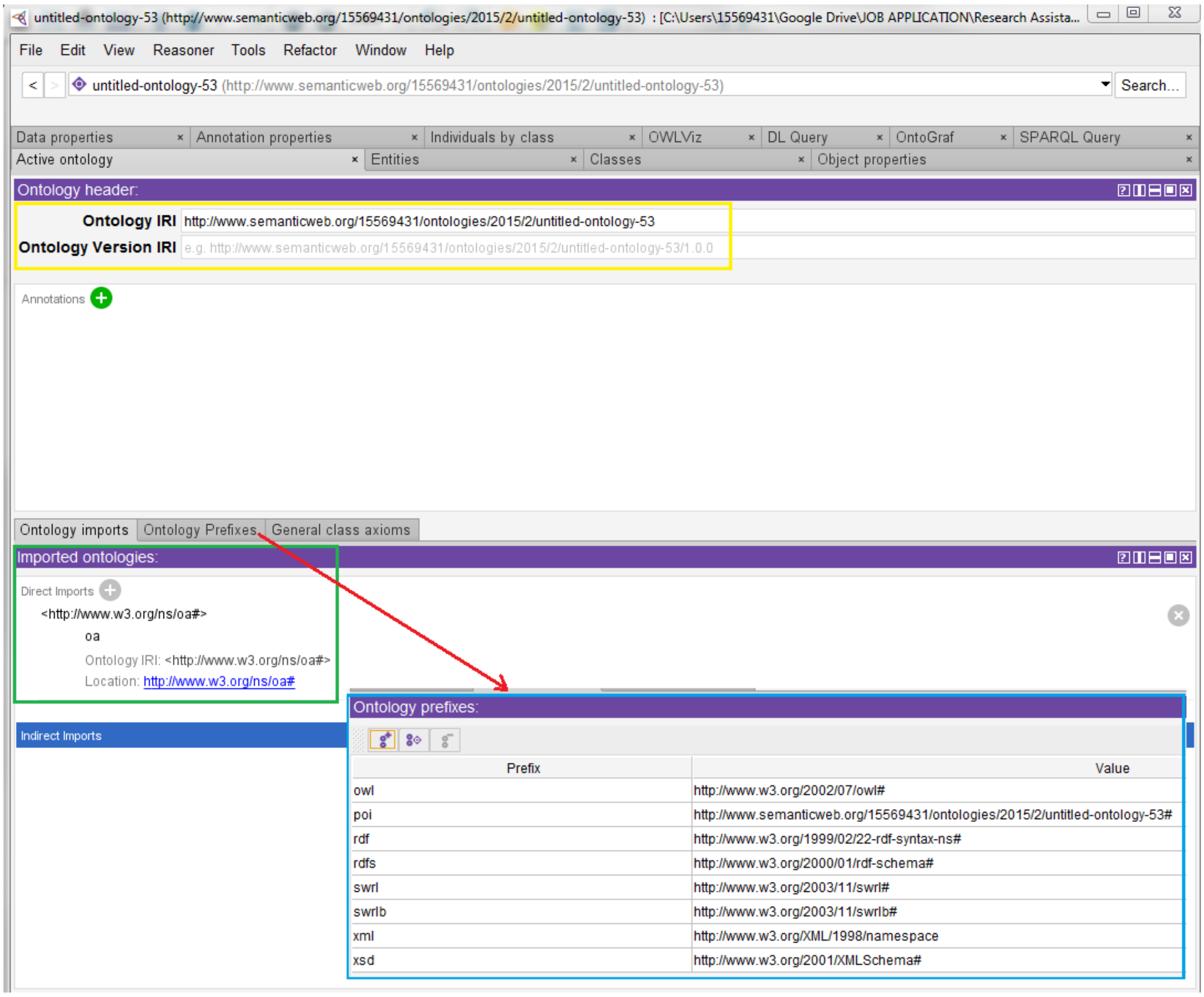

Figure 4.10 Protégé user interface

4. 4 Summary

This chapter focuses on the ontology structure, development method and tools for generating geospatial data conflation ontologies. An ontology defines a collection of concepts and the relationships between those concepts for a course of domain. It provides common background knowledge and aims to be shared and reused among the domain communities. Various traditional formats of geospatial data that are transformed into the RDF format based on ontologies will be encoded with semantics explicitly. It helps to overcome semantic heterogeneity issues among different geospatial datasets that come from different organisations and enables effective geospatial data conflation. Formal ontologies developed using standard web ontology languages such as OWL are machine readable and can be processed by reasoners. Therefore, formal ontologies are an important factor for realizing automatic geospatial data conflation.

Ontologies are commonly categorised into three levels, i.e. top-level ontologies, domain ontologies and application ontologies. Top level ontologies are normally referred to as those developed by international standardisation organisations such as W3C Geospatial Vocabulary[67] or OGC GeoSPARQL. These are aimed at a broader range of data integrations such as cross domain data integration or general data integration across the Web. Top-level ontologies are designed to be lightweight and easily extensible for specific application needs. Domain ontologies aim at specific domains of interest and are still much in need of standardisation efforts. Generating domain ontologies based on existing standardised domain data models is a good starting point towards standardised domain ontologies and can help reduce duplicate efforts. The Foundation Spatial Data Framework (FSDF) is a great standardisation initiative that aims at providing foundational geospatial data for Australia by reducing duplicate geospatial data and integrating disparate local government and state government level data into a national-wide dataset. The standardised data models for different data themes developed through FSDF activities are appropriate sources for developing Australian wide standard domain ontologies. Application ontologies developed based on domain ontology are sharable and interoperable between applications within the domain which in turn will greatly reduce data heterogeneity issues and improve the data conflation processes.

[67] https://www.w3.org/2005/Incubator/geo/XGR-geo/

5 SWRL RULE ENGINEERING FRAMEWORK

In the previous chapters, two main Semantic Web technologies (i.e. RDF and ontology) implemented in the geospatial conflation system were discussed. Each of the technologies' benefits and some of its technology implementation aspects were presented respectively in Chapter 3 (regarding RDF) and Chapter 4 (about ontology). This chapter will focus on the remaining technology applied in the geospatial conflation system, i.e. SWRL[68].

SWRL rules are an essential part of this research. Engineering SWRL rules are involved in each stage of the implementation including high-level ontology generation, aligning data instances, matching relevant objects and reasoning among matched candidates.

This chapter aims at generating SWRL rule chains to model users' analytic logic and reasoning steps to automate the conflation decisions. The SWRL rule chains can combine various information such as provenance, topological relationships, policies, business rules and user experience in a declarative way and are used to reason on top of data instances.

5. 1 Extending OWL 2 reasoning functions through SWRL

Ontologies provide essential semantic mark-up vocabularies that are necessary for the Semantic Web, and are therefore considered as playing a key part in the Semantic Web (Golbreich, 2004). Ontologies are developed for defining concepts (a.k.a classes) in a domain and expressing relations (in the form of properties) between concepts. OWL DL ontologies provide extra mechanisms to enable powerful reasoning and inference over relationships, typically class-subclass relationships and class-individual relationships. Rules are also required for the Semantic Web and according to the Semantic Web technology stack (see Figure 1.2), rules operate on top of ontologies. The Semantic Web Rule Language (SWRL) is a web rule language that has become a W3C standard since 2004 (Horrocks et al., 2004). It was

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[68] https://www.w3.org/Submission/SWRL/

developed based on a combination of the OWL DL and OWL Lite sublanguage of the OWL language with the Unary/Binary Datalog RuleML sublanguages of the Rule Markup Language. According to Eiter, Ianni, Krennwallner, and Polleres (2008), SWRL is more than a cheap add-on to the OWL standard and is adding advanced reasoning capabilities to it. SWRL is a specification that extends the OWL standard syntactically and semantically and provides further reasoning about OWL individuals relationships based on OWL concepts. New knowledge can be inferred from existing OWL knowledge bases through SWRL rules.

The formula of rules looks like *antecedent* => *consequent* which means 'if [body] then [head]' corresponds to logical thinking. The antecedent (or body) contains one or more conditions to be met in order to get the consequent (or head) to be true. The consequent can also be more than one atom. A simple rule example in human readable syntax looks like Figure 5.1 which means if a person x has a brother y and has a sister z, then y and z can be inferred as siblings too.

hasBrother(?x, ?y) ^ hasSister (?x, ?z) -> hasSibling (?y, ?z)

Figure 5.1 A simple rule example

Klien (2007) pointed out that ontologies have been increasingly used in the geospatial domain for improving data access. Formal ontologies used in the geospatial domain greatly improve semantic interoperability, which can effectively improve data discovery and data retrieval based on data content. As a result, it in turn increases the needs to provide methods and tools for data providers to semantically annotate geospatial data easily so the ontologies can become more widely accepted by the geospatial community. The semantic annotation of geospatial data is defined as the mapping between data schema elements and domain ontology elements. However, the mapping is not always straightforward as conceptualisation of the same geospatial entities can be quite different by different user communities. The solution starts with defining geospatial concepts and their spatial characteristics (including spatial relations and properties that are important for characterizing geospatial entities) in OWL ontologies. Then SWRL rules are proposed to define a set of spatial conditions where data instances from a database must all meet those conditions to be able to be classified as a certain concept (or class). Then a refinement of the classified concept based on the data instances is done in the next step and can be mapped to a concept defined in the OWL ontologies, therefore realizing the semantic annotation. Such SWRL-based strategy provides a foundation for the development of semantic annotation tools in the geospatial community. As the work of Klien (2007) has demonstrated, SWRL can be effectively used in geospatial applications which works on top of geospatial OWL ontologies and allows further inferring on geospatial data instances. Some of the expressive limitations of ontologies can be overcome by adding the rules to the ontologies.

5. 2 Geospatial Data Conflation Reasoning Using OWL Ontologies and SWRL Rules in Combination

Theoretically, ontology languages adhere to the Open World Assumption (OWA). The OWA assumes knowledge is not untrue when knowledge is not available or cannot be derived from an ontology, and it only means such information is incomplete in the ontology and conclusions cannot be thus derived. Rule languages on the other hand, adopt the Closed World Assumption meaning knowledge that is not explicitly specified or is not derivable from the knowledge base is deemed to be false. Therefore, rule languages are complementary to ontology languages; where prescribed requirements cannot be fully met by ontology languages and where rule languages can help to resolve at least some of them (Eiter et al., 2008).

Technically speaking, both OWL ontologies and SWRL rules are able to represent knowledge and perform reasoning but have their own advantages and are suited better for some particular types. “Structured” knowledge like classes, properties and taxonomies are better represented by OWL ontologies while SWRL rules are better at expressing “deductive” knowledge where knowledge is not primitively presented but derived from some other information through defined rules; automatic classification and class recognition of instances are the types of reasoning well performed in OWL ontologies but SWRL rules can answer queries and infer new information (Golbreich & Imai, 2004). Therefore, OWL ontologies and SWRL rules can work closely together to realise full inferences.

A step beyond creating SWRL rules using the OWL ontology vocabulary is to enable reasoning OWL ontologies and SWRL rules to work together in a consistent way. That is, not only ensure SWRL rules and OWL ontologies are syntactically and semantically interoperable but also inferentially interoperable, therefore, inferences can be drawn based on the combination of OWL ontologies and the SWRL rules (Golbreich & Imai, 2004). A platform that allows users to easily create and edit SWRL rules using OWL classes, properties and individuals within an ontology, and can seamlessly run reasoning on top of both OWL ontologies and SWRL rules is of great value.

A convenient ontology editor, i.e. Protégé, which was introduced in the last chapter, offers mechanisms to realise such interoperability requirements between SWRL and OWL. Protégé not only provides a user-friendly interface for creating OWL ontologies but also allows users to seamlessly switch to generate SWRL rules at the same interface. Users can incorporate OWL entities they have been generated to author SWRL rules then using reasoning on both OWL ontologies and SWRL rules at the same time with the Protégé built in reasoner (O'Connor, Knublauch, Tu, & Musen, 2005). Protégé automatically checks if syntactic and semantic errors occur during the generation process of SWRL rules and ensures any OWL entities referred to are valid.

In chapter 4, the *WA Topographic: Points of Interest* data model is introduced as an example for generating the *Points of Interest (POI)* ontology for this research. SWRL rules are also created as part of the *Points of Interest (POI)* ontology and used for inferring implicit properties for classes or individuals in the ontology. Those SWRL rules are created in Protégé as well and therefore, can directly use the POI ontology entities that have been created.

A snapshot of both the POI ontology and rules working together in Protégé is shown in Figure 5.2. It demonstrates the combined use of class-subclass relationships in the POI ontology, together with several rules that make use of the ontology atoms to infer a classification code for any POI. A Classification code is one of the important attributes for POI data models. It is a 6-digit code derived from the combination of POIClass (a 2-digit class code), POISubtype (a 2-digit subtype code) and

POIDomain (a 2-digit domain code) values to allow the reconstruction of the classification system. This unique classification format is essential for a POI. The classification code can be used as one of the metrics to decide whether two POIs are the same. For example, a supermarket (classification code is *070603*) and a medicare centre (classification code is *050503*) located in the same building may have the same coordinates and address, but because their classification codes are different, they can be ruled out as being the same POI.

However, not all source datasets include the classification code as an attribute. For example, if a source dataset only has a *POIDomain* value, such as a POI named *FESA_257* shown in the top left of Figure 5.2, which is at the bottom of the hierarchy to represent the whole classification system, *POISubtype* and *POIClass* need to be identified before a classification code can be formed. This process is implemented as two steps, first at the ontology level (see Figure 5.2) and then at the data instance level (see Figure 5.3).

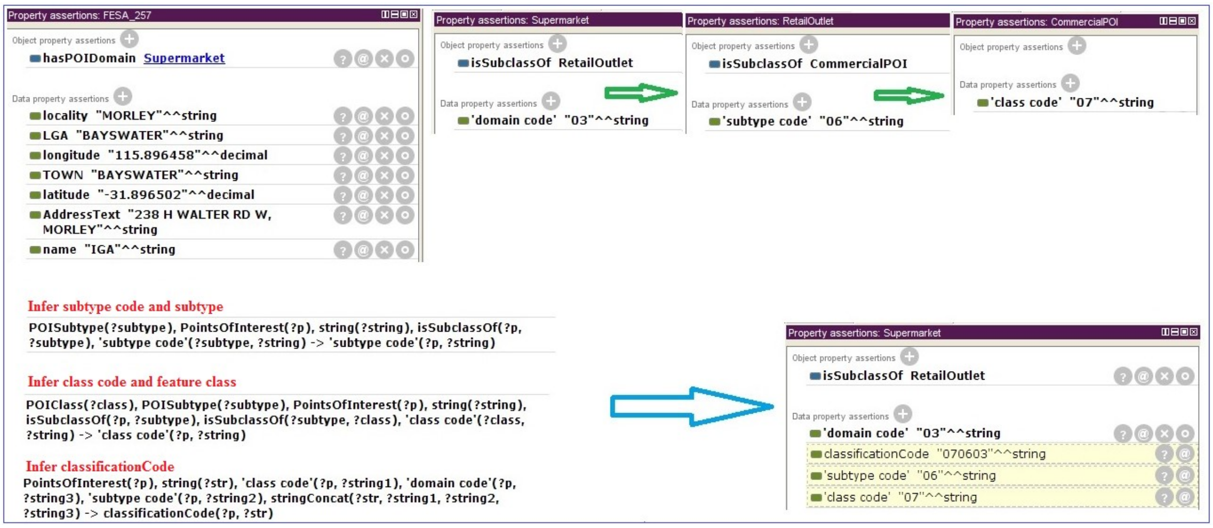

Figure 5.2 Rule examples of inferring subtype code, class code and classification code for the “Supermarket” domain at ontoloy level

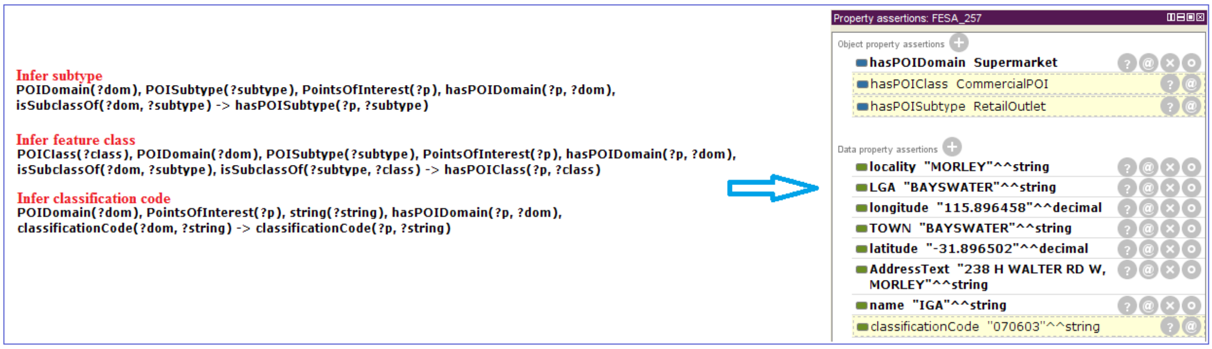

Figure 5.3 Rule examples of inferring subtype code, class code and classification code for the “Supermarket” domain at data instance level

The classification codes can be determined by specified ontology relationships such as: a *POIDomain* is the subclass of the *POISubtype*, and *POIClass* is the superclass of the *POISubtype* (see the example relationships between *Supermarket*, *RetailOutlet* and *CommercialPOI* in the top right part of Figure 5.2), together with chains of rules that makes use of these relationships (See bottom left part of Figure 5.2). The inferred properties for Supermarket can be seen at the bottom right part of Figure 5.2 and inferencing happens at the ontology level for all feature domains.

Then, after POI data instances are transformed into RDF format based on the POI ontology, the missing attributes in the data instance can then be filled by another set of SWRL rules. This inference step happens at the data instance level using the inferred results from the ontology level. For example, the POI named *FESA_257* in Figure 5.3 is known to have a *POIDomain* value as Supermarket, and the properties of superclasses and classification code for *Supermarket* are also known from the ontology level inferences, hence *FESA_257* can be inferred to have the same properties as Supermarket. Note all the inferred information is highlighted in yellow in the property list.

5. 3 Improve SWRL Rules Performance through Custom Built-Ins

Another important feature of SWRL is that it offers a series of built-in predicates that greatly extend SWRL’s expressive power (O’Connor et al., 2005). SWRL built-ins are designed to comply with modular approaches to allow flexible implementation. There are seven sets of built-ins defined in the SWRL specification:

- *Built-Ins for Comparisons* set allows comparison between two values (not necessary numeric values) such as whether or not two numeric values are equal (*swrlb:equal* or *swrlb:notEqual*), or which value is greater or less than the other (*swrlb:greaterThan* or *swrlb:lessThan*).
- *Math Built-Ins* set provides mathematical functions to allow further operations on numeric type values within the SWRL rules. These range from the basic math operations, e.g. add, subtract, multiply and divide (*swrlb:add*, *swrlb:subtract*, *swrlb:multiply* and *swrlb:divide*), to the more advanced functions, e.g. sine, cosine and tangent (*swrlb:sin*, *swrlb:cos* and *swrlb:tan*) etc.
- *Built-Ins for Strings* which can be used for string type values comparison, for instance whether two strings are equal regardless their case (*swrlb:stringEqualIgnoreCase*) or even enables users to perform actions like replace one string with another string (*swrlb:replace*).
- *Built-Ins for Date*, *Time and Duration* are also commonly used for identifying date, time elements or duration operations. Predicate examples are *swrlb:date*, *swrlb:time* and *swrlb:yearMonthDuration* etc.
- The remaining built-in sets are *Built-Ins for Boolean Values*, *Built-Ins for URIs* and *Built-Ins for Lists*.

Keßler et al. (2009) showcase how SWRL rules incorporating basic numeric value comparisons and distance calculations can be used to effectively retrieve geographical information matched according to user's preferences. The preferences are for example, a surfer wanted to find a surf spot where the current wave height is less than 1.5 metres, the water bottom is sandy to ensure safety, and the surf spot distance is within the 0.5 degree differences radius for both latitude and longitude from the surfer's current location (the surfer's latitude and longitude are known). Such preferences are converted into conditional variables in a SWRL rule (see Figure 5.4) and the authors demonstrated the mathematical calculation could be done using default built-ins for SWRL (marked inside a red rectangle in Figure 5.4). The calculation starts after a variable location is retrieved and operates in three steps. For example, the first step is to use *swrlb:subtract* built-in to get the difference between the retrieved latitude and the known latitude. The second step is to get the absolute value of the difference using *swrlb:abs* built-in. The last step is to compare the absolute difference value with the 0.5 degree radius threshold by using *swrlb:lessThanOrEqual*. The same processes are applied to longitude pairs to decide whether the retrieved value meets the conditions (preferences set by the users). Such a SWRL rule-based strategy for retrieving context-based (user's preference) geographical information helps to overcome some limitations of OWL ontologies that are not able to perform free variable reasonings and only static information available in the ontologies.

```
SurfSpot(?spot) ∧
hasWaveHeight(?spot, ?height) ∧
swrlb:lessThan(?height, 1.5) ∧
isAtLocation(?spot, ?location) ∧
hasLatitude(?location, ?lat) ∧
hasLongitude(?location, ?lon) ∧
swrlb:subtract(?distLat, ?lat, 34.412132) ∧
swrlb:subtract(?distLon, ?lon, -119.68913) ∧
swrlb:abs(?distLatAbs, ?distLat) ∧
swrlb:abs(?distLonAbs, ?distLon) ∧
swrlb:lessThanOrEqual(?distLatAbs, 0.5) ∧
swrlb:lessThanOrEqual(?distLonAbs, 0.5) ∧
hasBottom(?spot, ?bottom) ∧
SandyBottom(?bottom)
→ AppropriateSurfSpot(?spot)
```

Figure 5.4 Calculation example using default SWRL built-ins in Keßler et al. (Keßler et al., 2009)

However, the calculations demonstrated by Keßler et al. (2009) using default built-ins might lead to a decrease in rule efficiency, especially if the data source is real-time and each calculation needs to communicate to the server to get the data. It would be beneficial to hide these detailed calculation steps at the backend in faster lower level code and use a single predicate instead. Therefore, the ability to support custom built-ins is another powerful feature of SWRL that is worth considering.

The default built-ins for the SWRL are targeting common mathematical and string operations (Horrocks et al., 2004) but SWRL also allows users to define their own libraries of built-ins and used as predicates in SWRL rules (O'Connor, Shankar, Nyulas, Tu, & Das, 2008) to meet their application needs. For example, the series of calculation steps and separation of latitude and longitude processes can be wrapped into a single predicate *swrlb:distance(?Location1, ?Location2, 5)* instead. Such a proposed built-in, taking into account a surfer's location, is also dynamically retrieved from a date source instead of hard coded into the rule, and directly returns the distance between the two locations with a single value (such as 5 kilometres) instead of 0.5 degrees each for latitude and longitude.

The suggested built-in function is similar to the idea in the work of H. Chen et al. (2005), which also needs to calculate distance between two locations, in a bus route planning application (see the highlighted parts in Figure 5.5). Chen et al. proposed rules that are to be used in Geospatial Semantic Web applications where geospatial data semantics have been explicitly defined using ontologies (referred as high-level logic). Then these rules can be used to define procedures for processing the data (referred to as a low-level implementation that is guided by high-level computational logics). Chen et al. pointed out that one of the requirements for Geospatial Semantic Web application implementation is that it should support built-ins that can perform geospatial functions, such as *locatedIn*, *distanceFrom*, *overlaps* and *contains* etc. The support of custom built-ins is particularly useful for geospatial applications as there are functions normally involving a lot of calculations for geometric attributes.

```
RULE1: IF distanceFrom(?locA, ?locB, ?dist) AND
          lessThan(?dist, 100, "meters") AND
          isTypeOf(?locA, fea:RoadIntersection) AND
          isTypeOf(?locB, fea:ShoppingMall)
       THEN
          busStopCandidate(?locA)

RULE2: IF busStopCandiate(?locA) AND
          existingBusStop(?locB) AND
          distanceFrom(?locA, ?locB, ?dist) AND
          lessThan(?dist, 700, "meters")
       THEN
          not(busStopCandidate(?locA))
```

Figure 5.5 Proposed rules for bus route planning (H. Chen et al., 2005)

Common spatial processing functions, such as *Buffer, Union* and *Intersection*, can be developed into spatial processing built-ins, and spatial relationship functions, such as

Within, Disjoint and *Overlap*, can be developed as spatial relationship built-ins to provide rule-based spatial analysis capabilities (Karmacharya et al., 2010, 2011). A translation engine is required to translate Spatial SWRL rules (rules using spatial built-ins) into standard SWRL rules. The work in Karmacharya et al. (2011) is aiming at a step further to incorporate the spatial analysis functionalities within the Semantic Web framework so it can be seamlessly utilised with other Semantic Web technologies. Therefore, the authors proposed to add a layer containing spatial information into the Semantic Web technologies stack, see Figure 5.6. They emphasise the use of spatial operations and functions terminology standardised by the OGC instead of commonly used terms to avoid confusion and ambiguity between applications. The way to integrate spatial technologies into the Semantic Web stack is proposed to define a new kind of FILTER based on spatial relationship functions for SPARQL queries, and Built-ins for SWRL rules based on spatial processing functions. The first part of the idea has been realised by GeoSPARQL (Perry & Herring, 2012) and published later by the OGC, which is the standard query language for geospatial data in RDF. However, the part of spatial processing built-ins for SWRL has not been standardised so far and is not supported in ontology editors, such as Protégé, to create standard SWRL rules.

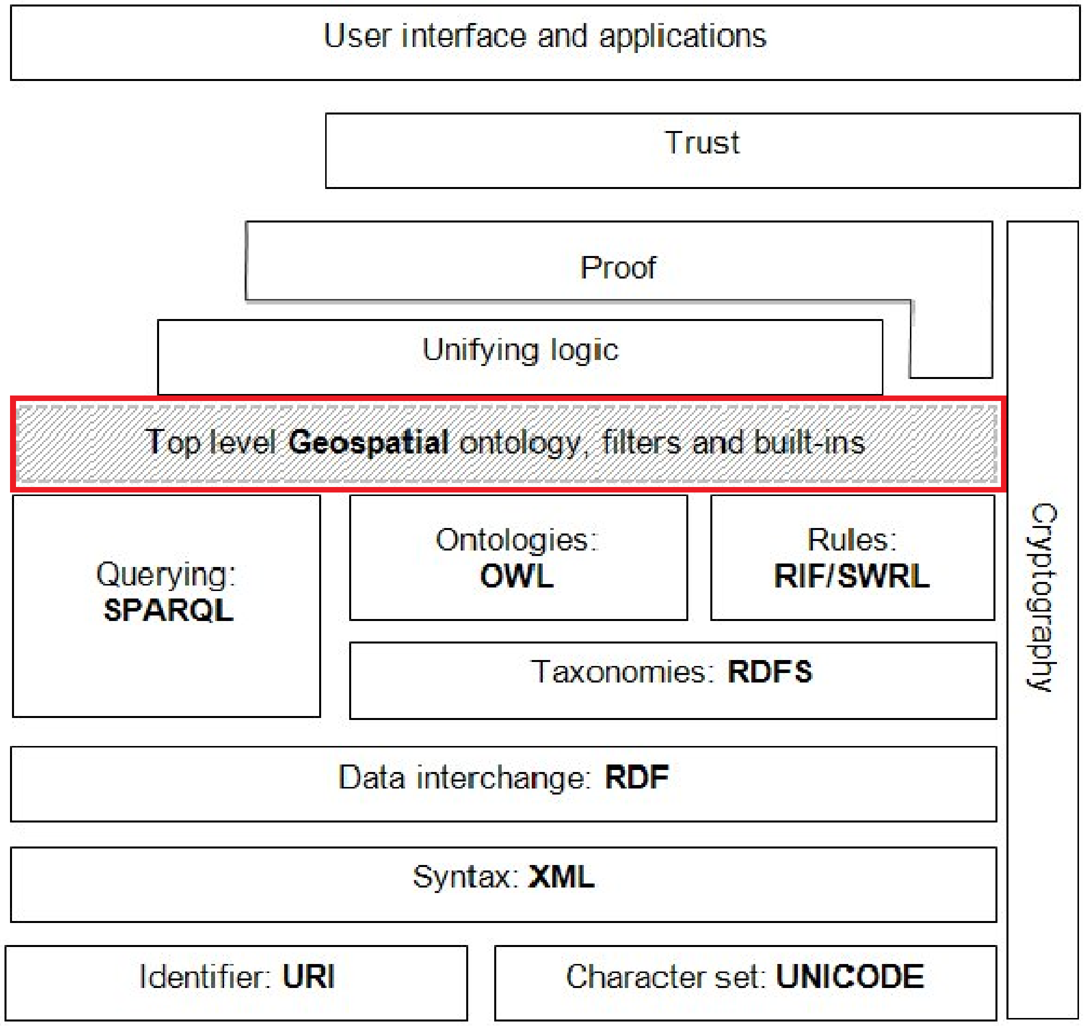

Figure 5.6 Semantic Web stack adjusted with spatial component layer (Karmacharya et al., 2011)

5. 4 Replicate Human Reasoning in Geospatial Data Conflation Process with Chain of SWRL Rules

From the literature reviews regarding geospatial data integration or data conflation, most of the research focused on resolving data heterogeneity issues involving syntactic, schematic and semantic levels. Their work normally aims at performing one or more specific tasks such as data discovery, data retrieval, and data matching and linking that can meet data requirements for a specific application purpose. However, there is little literature that discusses what happens after syntactic, schematic and semantic heterogeneity problems have been solved. In this work, it is argued that there are data value heterogeneity problems that exist besides the three levels' heterogeneous issues that need to be resolved. For example, once the linkages established and attribute values from different sources are brought together, it is necessary to decide which value is the most accurate or most fit-for-purpose so the source datasets can be conflated into a single dataset. Furthermore, if there is more than one dataset from the same theme that meets the data requirement conditions, it will bring in data duplication issues, i.e. each containing feature that describe the same real-world objects. Therefore, it is even more difficult for people to decide which data is the best or best suited for the application purposes. The manual process is to identify the best features from each dataset and remove duplicates. This process will differ depending on the data required and purpose for which the data is to be used.

How to make the decision of which data is chosen (based on what information) and how to automate the process of the decision are much needed research topics. While matching and linking processes have been performed semi-automatically or automatically by computer algorithms, the conflation process is difficult to automate with algorithms (Beeri, Kanza, Safra, & Sagiv, 2004) because it requires decision making to not only look at the data themselves but also to refer to other information or knowledge. It is hard for the computer to do that because it requires typical human (domain expert especially in the geospatial domain) intervention process. The process requires holistic information combined from various sources, including but not limited to reference data, business rules, metadata, provenance, topological relationships and even the domain expert's experience and knowledge, stemming from their years of work, being used in some kind of logic and performing the logic in sequential reasoning steps.

Currently, there is no single application that can do the whole comparison and decision-making process automatically. While domain experts can use logic and reasoning to complete the conflation work, the workload is intensive and time consuming, and close to impossible for them to do on a case-by-case basis. There is a significant amount of effort required to identify the strengths and weaknesses in each data source, even before designing a semi-automated integration solution. In addition, the effort required to compare data sources is extremely labour intensive and subjective when dealing with multiple large datasets. Therefore, human intervention is heavily relied on regarding choosing the best or the most appropriate value at the current condition.

As has been discussed in the earlier sections, SWRL has many advantages in performing reasoning processes and is flexible in terms of extending its expressivists through building custom built-ins. Hence in this research we use SWRL to generate formal rules for computers to do the reasoning process instead of humans. These formal rules could be extracted from human regular reasoning processes, existing policies, domain knowledge and the expert's experience to minimise human intervention and automate the conflation process.

5.4.1 An Example Scenario of Geospatial Data Conflation uses SWRL Rules

In this research, the case study starts with a simple scenario in which a GIS analyst in an emergency department needs to provide accurate location data for emergency responders. Location is regarded as one of the most important attributes of a spatial feature as emergency responders can uniquely locate an incident if the nearby point of interest (POI) has the coordinates (latitude/longitude pair) or an address (Adams et al., 2010). However, if there is more than one data source for points of interest or if there are duplicate POIs in a dataset, the GIS analyst is required to conflate the multiple sources into a single authoritative dataset to enable emergency responders to quickly and accurately locate the incident location without any confusion.

The conflation process starts with initial data filtering based on location proxy and address similarity that can identify a list of corresponding candidates. These candidates will then be carried into the next step for more sophisticated reasoning to determine whether they are truly matched or to decide which location is the best based on user requirements or other constraints. An example can be seen in Figure 5.7a, where a school POI is indicated by the red circle. An initial filter based on distance calculations is performed to identify possible matched points. In this case, a distance threshold of 200 metres is used. Four candidates are available from the initial filtering (Figure 5.7a). The question is, which location is the right one for use?

In the current environment and work practices, this is normally the time for human intervention. For example, a property or parcel boundary from a cadastral dataset can be brought in to rule out points that lie outside the boundary (see Figure 5.7b). The next step is to examine the metadata, which might record the source location information for each dataset. As shown in Figure 5.7c, one candidate is located in the administration building, one is captured at the main entrance and the other is recorded as the parcel centre or centroid. A decision is made to keep the main entrance location based on the user's requirement of the conflated dataset that is to provide accurate location information about the access point to the school for an emergency responder.

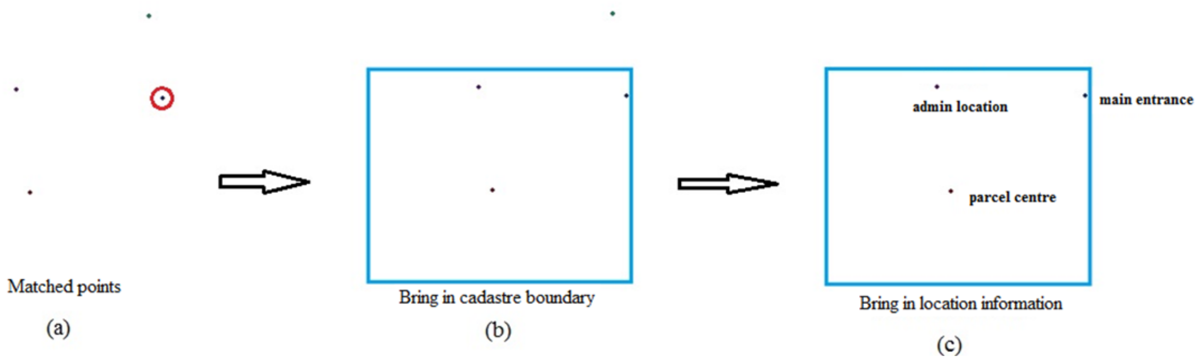

Figure 5.7 Reasoning process

For automatic data conflation, the filtering and reasoning process described above can be transformed into a chain of rules that can be invoked. Such rules written in the Semantic Web Rule Language (SWRL) format include:

(a) Rule 1 - Initial filter: Find potentially matched points based on distance:
    PointOfInterest(?x) ^ PointOfInterest(?y) ^ Distance (?x, ?y, 200) -> matchedPoints(?x, ?y)
(b) Rule 2 - Compare to the cadastre boundary and rule out the ones outside the boundary:
    PointOfInterest(?x) ^ Polygon(?y) ^ hasWithin(?x, ?y) -> candidatePoint(?x)
(c) Rule 3 - Refer to the user's requirements to find the most suitable location which should be an entrance:
    locatedIn(?x, Admin) ^ locatedIn(?y, Entrance) ^ locatedIn(?z, Centre) -> keepLocation(?y)

Rules are the essential part of this research. Rules can infer new information from information that already exists. Inferred new information can be stored as new RDF triples and used in other rules for new assertions, in combination with information in existing triple stores. Chains of rules appear to be working together because they are running in sequence, but in fact they are totally independent. Rules only look for triples that they know how to deal with and then create new triples based on those known. So inference rules can be written using the results from other rules without explicitly coordinating all of the rules together (Segaran, Evans, & Taylor, 2009).

5.4.2 Knowledge Types for Geospatial Data Conflation Rules Generation

The design of the data reasoning process is the core of this research. The design resolves how to use the many sources and types of knowledge to formulate rules in a machine-readable way so that it minimises human intervention through automatic processes; and how to combine these rules in a proper sequence to get the best performance from the reasoning. The types of knowledge identified in this research that can be used for the geospatial conflation system but not limited to them are listed below:

(a) Provenance: Provenance is considered a very broad topic and the definition can be varied depending on the context in which it is used. In the context of databases, data provenance is defined as records of the data origins and how data was processed before it was added into the database (Buneman et al., 2001). According to the W3C working definition of provenance (W3C, 2015), is a record of a resource that "describe entities and processes involved in producing and delivering or otherwise influencing that resource". The official W3C recommendation of provenance PROV-DM (Belhajjame et al., 2013) defines it as "information about entities, activities and people involved in producing a piece of data or thing" which more explicitly specifies that the three concepts Entity, Agent and Activity are involved in the 'creating' or 'delivering' of things and the way those concepts are related to each other. The high-level overview of PROV record structure can be seen in Figure 5.8. Note that the relations are meant to express the assertions about the past.

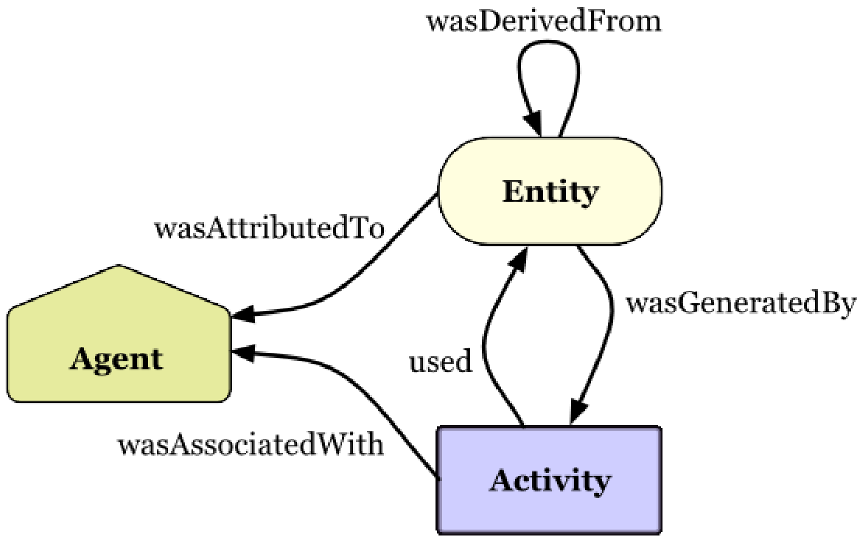

Figure 5.8 PROV structure high-level overview[69]

Provenance provides a critical foundation for assessing the quality, reliability or trustworthiness of data or things. People can make judgment calls regarding whether information is fit for use and effectively integrate diverse sources of information. The W3C PROV standard provides formal representations of provenance information that can be automatically interchanged among online systems and for reasoners to automatically make judgements about the information they use.

Efforts have been made to extend the W3C provenance standard to suit geospatial resources (including data, information and services) (Ivánová, Armstrong, & McMeekin, 2017). Ivánová et al. (2017) proposed extending PROV to model provenance of spatial resources with a trust score at both dataset and feature levels, therefore when data is discovered and returned against users' queries, it can be automatically assessed and determined for its fitness-for-use. The example illustrated is in the context of geospatial data discovery, however, the provenance of geospatial resources can definitely be used in the context of geospatial data conflation as well. Provenance information mentioned in the work such as the currency of the data (*prov:generatedAtTime*), the source of agency (*prov:Agent*) and the trust score of an entity (*prov:wasDerivedFrom*) etc. are all

[69] https://www.w3.org/TR/2013/NOTE-prov-primer-20130430/

important information to facilitate conflation decision making. When incorporating these elements into the SWRL rules, the decision processes can be automated.

(b) Business rules: ‘business rules’ is a common term that can refer to the specification of user defined rules in the database domain (Cockcroft, 1998). It is involved in part of the database design process where certain data integrity constraints are developed based on it to ensure data quality. Cockcroft (1998) demonstrated spatial rules are deployed in the spatial data repository to ensure data attributes and spatial relationships between entities are correct and complete. Business rules can also be the way you normally run your business or the set rules to resolve your business questions. For instance, the example demonstrated by H. Chen et al. (2005) for the bus route planning application in which a good bus stop candidate is needed to be less than 100 metres away from a shopping centre and at least 700 metres away from an existing bus stop. Such conditions are a form of business rules and can be used to form SWRL rules to exclude wrong candidates or retain good ones.

Similar usage can be deployed in the geospatial data conflation process. By writing business rules into SWRL rules, the reasoning mechanism can automatically decide which dataset is better based on whether the dataset meets the business rules. Formalised domain expert experience obtained from interviews through a knowledge elicitation process, and topological constraints are also aspects of the business rules.

(c) Statistical methods: for example, if several coordinates represent the same spatial entity or points of interest, without other conditions and constraints, rules are needed to decide the best one to choose. The reasoning process can use a statistical method to calculate the location, such as the mean, median or mode given that there are a number of justifiable alternative locations that provide the same information.

Spatial statistics methods are proposed to be used in order to generate feature type similarity or difference information to facilitate online geo-ontology alignments where lightweight ontologies alone cannot easily reveal the feature type relationships (Zhu, Hu, Janowicz, & McKenzie, 2016). Zhu et al. (2016) demonstrated using three spatial statistics analysis methods (specifically, spatial point patterns, spatial autocorrelations and spatial interactions with other geographic features) to generate statistical features from three well-known online gazetteers (i.e. DBpedia, GeoNames and TGN), and used those extracted statistical features to determine whether feature types are matched among those gazetteers in addition to using traditional alignment methods such as string similarity and structural measures etc. For example, where feature type names are the same in different gazetteers and have similar spatial patterns, they can be identified as the same feature types with high likelihood. However, where feature type names are also the same in different gazetteers, but their extracted statistical features are showing different spatial patterns, then they are considered to have different conceptualizations and not matched. The most significant contribution of the spatial statistics method is where very different names/labels are used in different gazetteers and traditional string matches would hardly return a match, the similar spatial patterns displayed by the statistical features can otherwise confirm those feature types are matched. Spatial statistical information shown in the research is seen as underlying semantics in addition to the semantics shown in the ontologies. It is important and valuable information that can be incorporated into SWRL rules to automate decision making.

(d) Contextual validation: Spatio-contextual information is regarded as valuable information in the remote sensing domain for supporting image classification, especially for the high-resolution remote sensing imagery classification (Li, Zang, Zhang, Li, & Wu, 2014). It incorporates spatial information which indicates the relationship between a ‘target’ pixel and its neighbouring pixels into traditional spectra-based classification methods to improve high resolution image classification accuracy. More broadly speaking, it is applying the previously rarely used geographic information analysis techniques that intend to address spatial dependence problems and are applied in vector data analysis into remote sensing image processing. Zheng et al. (2017) demonstrated how spatial contextual information can be used to facilitate effective identification of different types of rural settlements.

Contextual information is a broader range of information that first was proposed based on Tobler's first law of geography 'everything is related to everything else' (Tobler, 1970). Any information that can be used to characterise the situation of an entity such as place, person or object can be regarded as contextual information (Setiowati, Adji, & Ardiyanto, 2018). From a location recommendation system perspective, Setiowati et al. (2018) illustrated a wide range of aspects of context information including but not limited to time, location, activity, emotions, events and weather that can be used in the recommendation system to generate better quality and personalised recommendations to different users.

It should be beneficial to use contextual information to facilitate the decision making when conflation decisions cannot be made based on the information acquired through the source datasets alone. For example, using other relevant datasets as reference datasets to compute spatial relationships between feature objects and incorporate the relationship information into SWRL rules for reasoning, referring to users' needs to structure the conflation outputs, or using aerial photography, satellite imagery, street views and mobile mapping imagery to facilitate the validation of chosen information etc.

(e) Probability/Rating: in a real-world situation, people often need to deal with location information that is fuzzy or uncertain (Lin, Wang, & Watada, 2010). Therefore, when conflating source datasets that have random and fuzzy properties, the conflation process may need to incorporate probability information or produce probability outcomes for different strategies, e.g. a logical and systematic procedure. A logical and systematic approach is more efficient for decision making and more likely to produce most effective locations, such as the Fuzzy Probability Distribution Functions proposed by Lin et al. (2010), to decide a proper location for a facility during the planning process. O'Hanley, Scaparra, and García (2013) proposed forming a probability chain so it can be used in a specialised flow network for a compound probability terms evaluation to determine whether a facility location is reliable. The work of Espa, Benedetti, De Meo, Ricci, and Espa (2006) demonstrated GIS based statistical and predictive models can be used to generate probability maps of archaeological sites which is of crucial importance for archaeological research studies.

GIS practices quite often involve producing rating outcomes for various purposes such as rating for potential natural hazards. Ruel, Mitchell, and Dornier (2002) demonstrated how multi-layer information such as topographic indices of wind exposure and a digital elevation model can be used together in a GIS application (ESRI ArcView) to generate a windthrow hazard rating, which is important for forest windthrow management. Rockfalls are another natural hazard that can bring serious damage and is inconvenient to human and society. Baillifard, Jaboyedoff, and Sartori (2003) showcase how existing topographic, geomorphological and geological data in a GIS together with criteria that might indicate rockfall, can be used for analysis to effectively produce a rating hazard map. The methodology applied along a mountain road in Switzerland, identified several areas along the road that had a high rating of rockfall risks and where a rockfall did in fact occur. Rating is another means to show uncertainty or probability and can be used in the conflation process where different ratings can be adopted to meet different users' needs. Conflation processes can make decisions based on how likely the result matches the user requirements when an obvious solution is not likely to be produced. The decision is normally based on the highest rating that meets user requirements.

5. 5 SWRL Rule Engineering Framework for Geospatial Data Conflation

In this research, a general framework for guiding the engineering process of SWRL rules for the geospatial data conflation process is proposed in Figure 5.9. The principle of the SWRL chain is to model users' analytic logic and reasoning steps, and therefore, the knowledge acquisition process used to build the Knowledge Base repository for data conflation is performed at the same time as application development to understand the problems, extract relevant information and design a solution. When developers are shaping their decision logic with the acquired information, the same information is stored in the Knowledge Base repository. Once developers decide how to run each step and based on what knowledge, SWRL rules can be designed upon the same pieces of knowledge within the Knowledge Base and executed in the same sequence. Knowledge can be gathered from three hierarchy levels, starting from more application-related knowledge to domain-specific knowledge and common sense and expert knowledge.

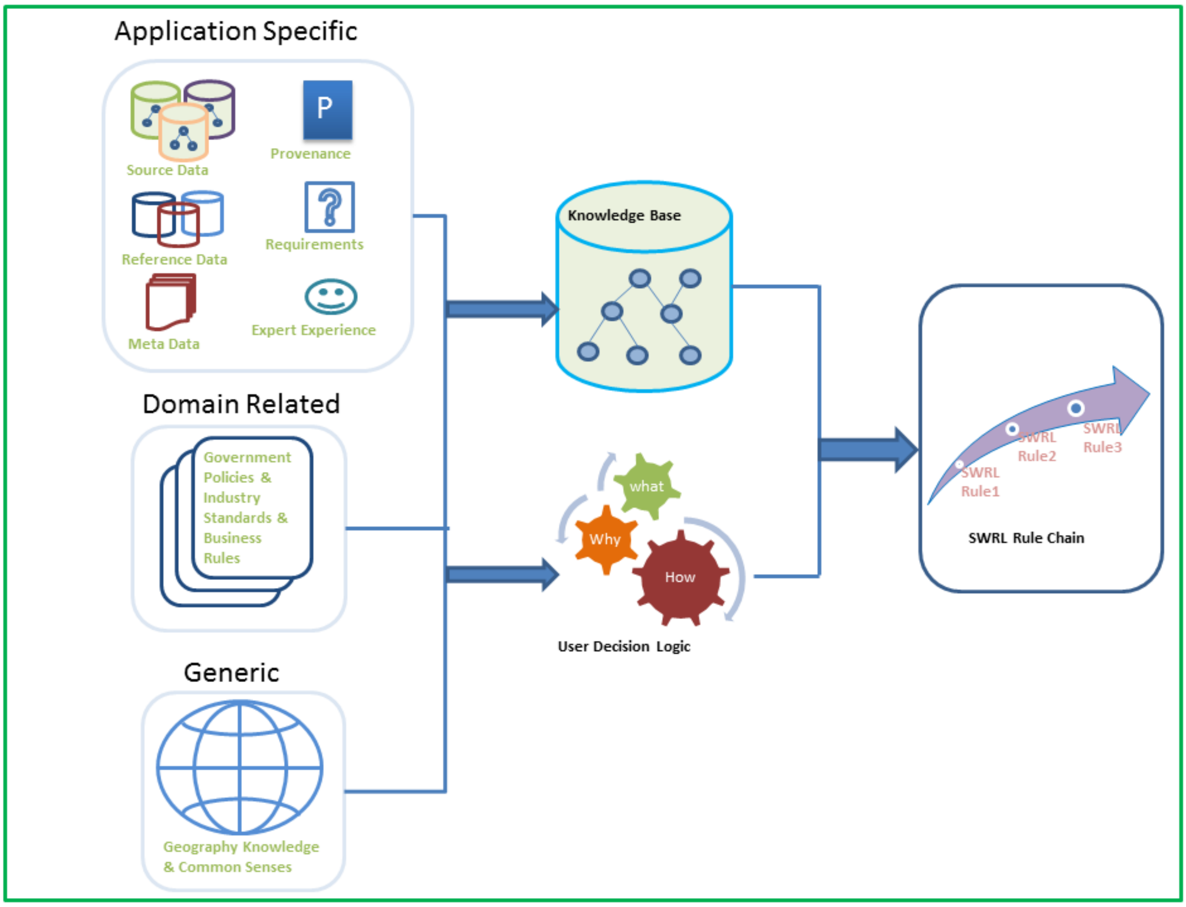

Figure 5.9 SWRL Rule Chain Engineering Framework

(a) **Application Specific knowledge** includes, but is not limited to, information from the following aspects:

(i) Source datasets: Feature attributes common across datasets to be integrated are a common element for dataset comparison such as latitude and longitude for geometric comparison, feature name or/and feature type for semantic comparison, and attributes required for the conflation. Only common attributes across source datasets are extracted.

(ii) Metadata and Provenance: metadata is to understand data meanings where data attribute names are not self-explanatory, and provenance information is used to understand how data has been processed. Both metadata and data provenance are essential for understanding source data quality.

(iii) Reference datasets: when users cannot figure out which feature to keep based solely on source datasets, other datasets can provide contextual information or topological relationships to facilitate a decision.

(iv) Application requirements: each application requirement (or user purpose) is unique and hence can lead to different data integration decisions and thus outputs, even when source datasets are the same.

(v) Expert experience: stemming from users' years of knowledge and experience working in a particular domain. It is not stated in any document but when an expert is interviewed it can help to effectively form part of the integration strategy.

(b) **Domain Related** information is broader than application specific needs. Domain related information applies to all applications in the same domain. Domain related information can be extracted from government policies, industry standards and business rules in order to guide the collection and processing of geospatial data for particular application domains. Some examples drawn from the topographic domain are:

(i) Emergency Services Domain: Fire hydrants are located on the side of a road.

(ii) Air Services Domain: An operational airport cannot exist without a runway or landing ground.

(iii) Geographic Names Domain: A road cannot have the same sounding name as another road within a 15km radius.

(c) **Generic** information comes from basic principles in geography or/and common sense to everyone. It is not specific to any domain but may be applied to any geographic relationships in the world. Such as:

(i) Tobler's first law of geography, which is the basis for finding matches between source datasets based on proximity – "everything is related to everything else, but near things are more related than distant things' (Tobler, 1970).

(ii) Streams flow from high to low so elevations upstream are higher than elevations downstream.

(iii) A cul-de-sac (no-through road) has only one entry and exit point.

The SWRL Rule Chain Engineering Framework developed in this research provides general guidance on the development of SWRL rules that apply logic and automatic reasoning for narrowing down and removing duplicate features when conflating multiple geospatial datasets. The more general information that can be used to describe the SWRL rules, the higher potential for rules to be re-used more extensively across applications.

5. 6 Summary

In this chapter, the W3C standard Semantic Web Rule Language (SWRL) and its advantages are introduced. SWRL is extended based on OWL but has more expressiveness power than OWL. Both OWL and SWRL have their own advantages and disadvantages and therefore their use can be complementary. Therefore, there are more benefits working with both technologies instead of selecting one over the other. The benefits brought by SWRL to the geospatial conflation process were discussed in this chapter as being able to replicate human reasoning processes by incorporating various knowledge, expert experience and human decision thinking into a chain of SWRL rules to automate the conflation process.

The utilisation of SWRL rules is the core of the ADGC system developed in this research. The traditional geospatial data process is often time consuming as it involves large amounts of human intervention to determine which data is the most appropriate regarding its data accuracy, currency and completeness. Human experts need to explore and apply various information and knowledge to perform geospatial data conflation processes. Such information and knowledge range from application-specific knowledge, to domain related policies, industry standards and business rules, to common sense or generic geography theories/principles. A SWRL Rule Engineering Framework is proposed in this chapter for guiding the SWRL rule engineering process that uses this information and knowledge.

Information and knowledge are extracted and expressed in a declarative way through SWRL rules and used automatically to conduct reasoning to compare, match and link duplicate data instances to identify a single real-world representation according to human logic. Such SWRL rules can be chained together to model human logic in the geospatial conflation processes to reduce human intervention and automate the conflation process.

In the next chapter, a case study demonstrates how semantic technologies, i.e. RDF, OWL ontology and SWRL, can be used to automate the POI data conflation process.

6 CASE STUDY

In the previous chapters, the three core Semantic Web technologies had been introduced and discussed respectively (i.e. Chapter 3 about common data structure RDF, Chapter 4 regards using OWL/OWL2 to generate ontologies, and Chapter 5 is about SWRL rules). This chapter aims to demonstrate how the proposed Automatic Geospatial Data Conflation (AGDC) system is implemented with these technologies. The system is tested with a motivating example by conflating three government agencies' Points of Interest (POI) data sets to fulfil different business needs. A Proof of Concept (PoC) web portal is also developed for users to explore the original datasets and relevant conflation results based on different conflation rule options.

6. 1 Introduction

The problem of duplication in the collection and management of spatial datasets is twofold. Firstly, duplication is costly for governments as it creates an unnecessary overhead in human and computing resources. Secondly, there is inconsistency between datasets meaning that the source of truth is not clearly understood, and end-users may make decisions using incorrect or outdated information.

This is particularly a problem for emergency services. Incidents are often attended by more than one emergency service organisation - ambulance, State and Federal police, fire and rescue, defense organisations and emergency volunteer associations. If each agency is using their own datasets there is a risk that information may be different to other agencies leading to poor communication and coordination between first responders. For example, each organisation typically collects location data (points of interest), such as education institutions, pubs and clubs, pharmacies and civic places, to enable dispatch operations and incident management. However, these location features are often collected using different means, from distinct sources and at different times. The characteristics of these features are also recorded differently. Sometimes this is for unique and specific business purposes e.g. police record locations where licensed firearms are held, where restraining orders exist, and where violent behaviour has occurred previously; whereas the fire department records the age and maintenance cycle of fire hydrants, location of arson and building floor plans. However, the more common reason why information is recorded differently is simply because there was no agreed standard for capturing and modeling information when these systems were first built.

Agencies are now coming to realise that collaborative data collection and shared resources is a more attractive alternative and one that makes incident management more effective. However, bringing multiple agency datasets together is problematic. Each agency believes that their information is the best and is unwilling to compromise on their perception of what is true. Therefore, the overarching aim of conflating datasets is to come up with a solution that satisfies the needs of all agencies. This requires a multipurpose model that includes an abstraction of all feature characteristics including attribute data, geometric representation, definition and positional accuracy, as well as a dataset that contains the most accurate and updated information.

6. 2 Motivating example

An initiative by Western Australia government agencies in 2009 called the Points of Interest Working Group (POIWG) was trying to conflate overlapping POI data from multiple agencies into a single, authoritative dataset to be shared by government agencies. A project named LOC8WA was then set up under this initiative. The project was managed by Western Australian state land authority Landgate in collaboration with the Department of Fire and Emergency Services (DFES) and the Western Australian Police (WAPOL). LOC8WA sought to conflate the POI data sets managed by each department into a single authoritative data set. Yet it failed because of the lack of human resources to do the intensive manual work including aligning source datasets, finding matches between different POIs, making appropriate decisions regarding duplicated POIs which one is the most accurate or the most fir-for-purpose etc. However, the need for conflating POI datasets still strongly exists among agencies.

The motivating example explored in this research builds on the unfinished case study from LOC8WA project which uses Points of Interest (POI) datasets from the three Western Australian authorities: Landgate, WAPOL, and DFES. There are many issues that complicate the conflation process:

(a) Each set of POI data was generated from various sources, for example, some of the Landgate POIs were extracted from topographic geodatabases or digitised from orthoimages; while DFES and WAPOL collected geospatial information for many of their POIs from individual company websites, Yellow Pages©, and other government resources where available. Thus, for a POI existing in each different dataset, the question is "Which location is the most accurate and authoritative?"

(b) Some features such as emergency telephones do not have an address at street number level. How do you identify the same POIs from different datasets?

(c) A shopping centre contains a supermarket, a fast-food outlet, a pharmacy and a bank branch. Each is a different POI but can have the same address and the same geospatial coordinates. How do you identify each of the individual establishments without conflating them to be a single point or location?

(d) Attribute inconsistency happens across and within datasets. For example, one attribute contains the full address text in the DFES dataset; while in the WAPOL dataset, a column contains the full address text, but the full address is also broken down into separate attributes including house number, road name and locality. An attribute representing the name for POI is found in both DFES and WAPOL datasets, but some of the POIs in Landgate's dataset have *Full_Name*, *NAME*, *DISPLAY_NAME* and *DERIVED_NAME* to represent a single point; while some of the POIs that should have all these entries, have no entries for these attributes. Hence, how can the conflated dataset have a unified attribute format and also fulfil each different agency's need?

(e) Even within the same dataset, data accuracy varies. For example, Landgate's POIs are extracted from a series of topographic databases ranging from 1:25000 scale to 1:100000 scale. The difference in accuracy means different decision-making rules are needed for a single POI. For example, consider two candidate POIs each from Landgate dataset (extracted from 1:25000 scale topographic maps) and WAPOL dataset (data acquired at 1:50000 scale). A rule can be used to retain the Landgate coordinates because its accuracy level is higher. However, the same rule cannot be used if Landgate's data is extracted from 1: 100000 scale.

Identifying matched POIs across three datasets and conflating them into a single POI is a complex process. A scenario where all three POI datasets related to a same region are combined is shown in Figure 6.1. To demonstrate the difference, a point representing a shopping centre is highlighted inside a red circle. This point is from the Landgate dataset and is represented by a small dot inside a building footprint. Whereas, the shopping centre is recorded in the DFES dataset as two red diamond shape points (highlighted within blue circles) located in a road intersection.

Noticeably, there are points inside the shopping centre with different categories such as supermarkets, bank branches and the post office. Around the shopping centre, there are other feature class points, bus stations, taxi ranks and fast-food outlets. The complexity or "confusion" in this situation is that some points are the same POI, but their location is different. This is because they were sourced from different departments; or many POIs have the exact location but cannot be treated as the same POI as they have different names and attributes.

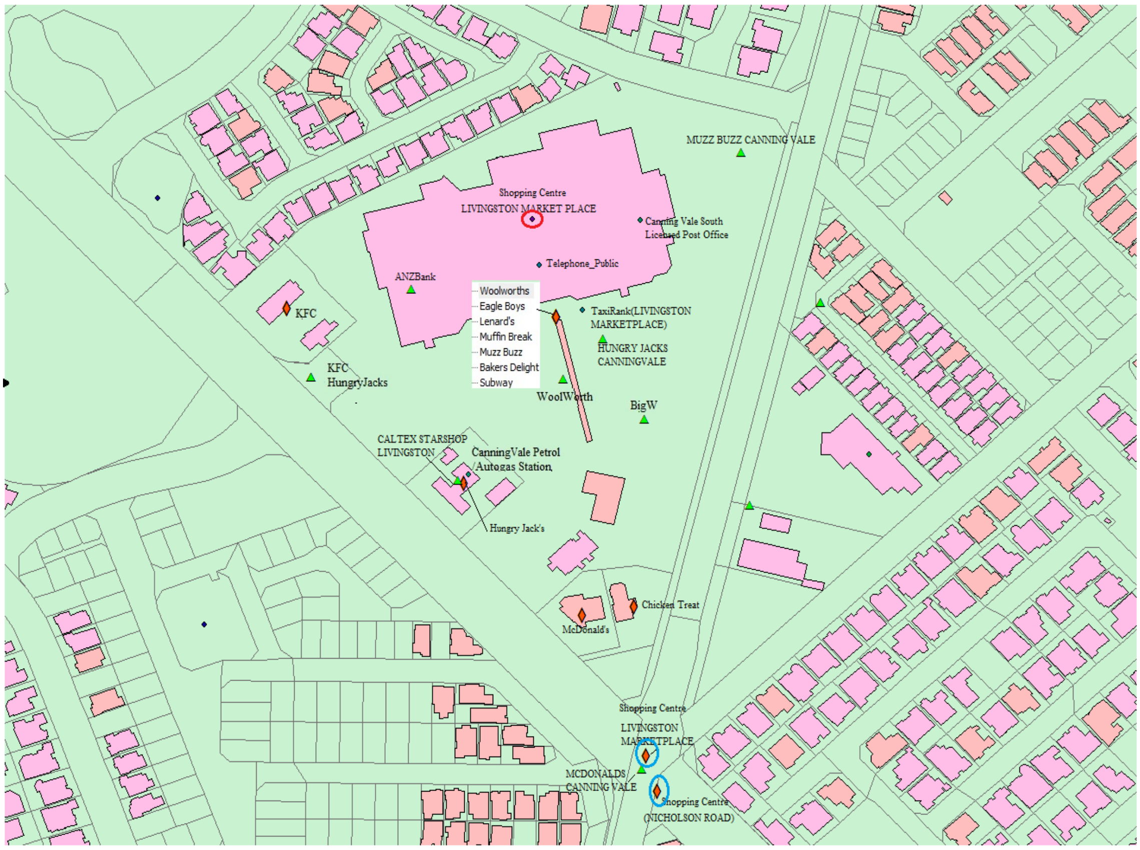

Figure 6.1 POIs distributed around a shopping centre area

The amount of human effort required to complete the task was considered too great to correctly identify matches and make correct conflation decisions on a case-by-case basis. There are tens of thousands of POIs in total from these three agencies. There is no single unique ID to represent the same POI across agencies' datasets, the same POI's location varies from dataset to dataset, and there is no consistent naming convention. Therefore, this case study intends to demonstrate the novel way to resolve issues faced by conflation process like "How can it be known that the three points from the different datasets actually correspond to the same POI, which POI attributes (of each point) are the most correct and which points and attributes should be removed?".

With current traditional GIS software, the issues identified above are difficult to resolve. The LOC8WA project did not generate a conflated dataset. Nonetheless, the importance of having an accurate POI dataset for emergency services still remains and this has given rise to the importance of this research and the use of LOC8WA for the case study for automated conflation techniques using advanced Semantic Web technologies conforming to W3C and OGC standards.

6. 3 Implementation

6.3.1 Stage 1: Ontology Development

The LOC8WA project uses Landgate's Points of Interest Data Model and participating agencies agreed that this model suited their business purposes. Landgate's Points of Interest dataset has been identified as a foundation dataset that belongs to the Place Name theme within the Foundation Spatial Data Framework. Therefore, the adoption of Landgate's POI data model as the multipurpose model for this study is complying with the standardization efforts within Australian as discussed in Chapter 4. The POI Ontology developed in this research is based on the Landgate data model and associated data dictionary. The POI ontology has potential to be adopted as a standard for all WA government agencies.

The essential knowledge in the data model was manually extracted and is shown in Figure 6.2 (the completed POI data model can be seen from Appendix A). It shows the classification system for the POIs, which complies with a three-level hierarchy where red, blue and grey rectangles represent feature classes, feature subtype and feature domains, respectively. A two-digit number following each hierarchy level value is the class code, subtype code and domain code, which together form a six-digit classification code number for each POI. Therefore, for any POI, it is categorised into one of the feature classes, such as *CommercialPOI* and assigned feature class code '07'. Within *CommercialPOI* feature class, the POI is further classified into one of the eight feature subtypes, for example, *RetailOutlet* subtype and its subtype code as '06'. Finally, the POI is representing a shopping centre, it is recorded as *ShoppingCentre* domain and is assigned a domain code as '02'. Then the classification code for this particular POI is '070602' by concatenating the three codes together.

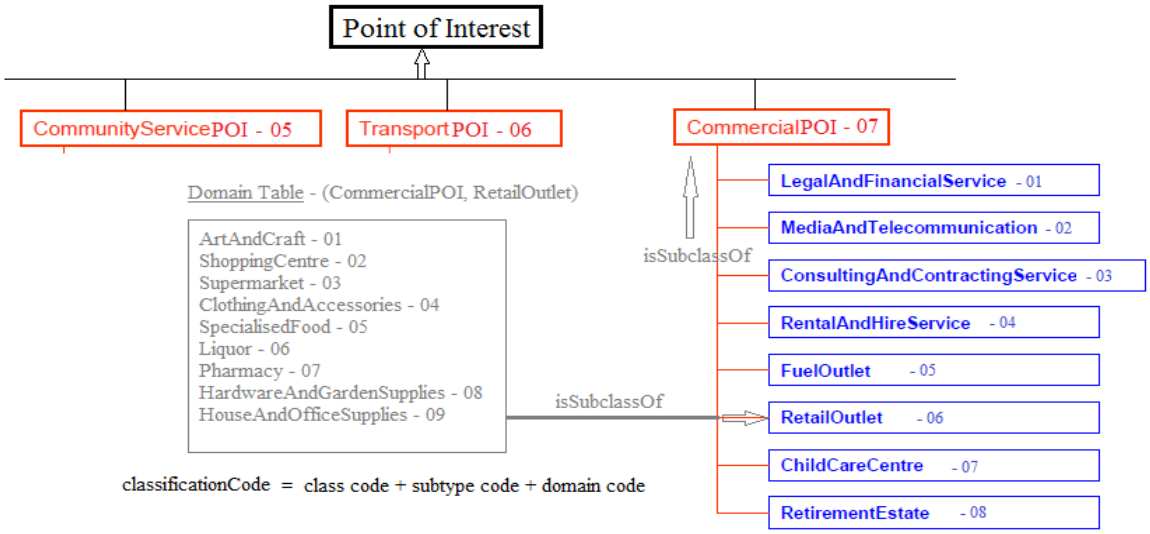

Figure 6.2 A portion of Landgate POI data model

The POI Ontology, designed according to the above structure, formally captures the scope of knowledge for Points of Interest using the OWL, so it is machine-readable, and reasoning can be done on the ontology. A part of the ontology corresponding to the same part of the data model demonstrated in Figure 6.2 is shown in Figure 6.3. There are three classes *POIClass*, *POISubtype* and *POIDomain* in the ontology and each represents a concept in the classification system, i.e. feature class, feature subtype and feature domain. On the right-hand side of each class are their individuals or instances. An example is highlighted in red at the bottom of the figure. The individuals showcased in *POIDomain* correspond to the "Domain Table" values in Figure 6.2. They are all feature domains relating to *RetailOutlet* feature subtype; hence all *POIDomain* individuals are pointing to the *RetailOutlet* individual which is a subclass of *CommercialPOI* as indicated by a yellow pointer. All other individuals enumerated in *POISubtype* class are subclasses of *CommercialPOI* as well. Individual features also have a data property to specify its two-digit code (see yellow box Figure 6.3) and information about whether it has a relationship with another feature using an object property (see yellow pointer Figure 6.3). The ontology in Figure 6.3 clearly demonstrates the information for individuals in each hierarchy level and their relationship with others; more importantly, these relationships are machine-readable so inferences can be drawn automatically.

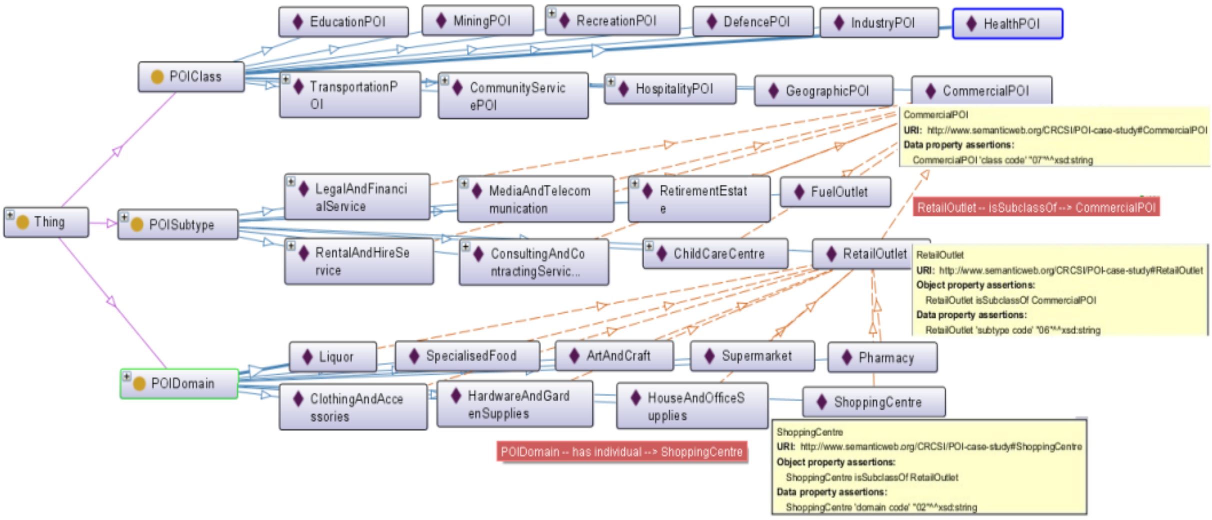

Figure 6.3 OntoGraf[70] representation for classes and instances based on POI data model

The classification code, which can be acquired by string concatenation of class code, subtype code and domain code, is an attribute of each feature domain. It has not been specified individually in the ontology as it is considered common knowledge for all the feature domains and can be inferred using a SWRL rule, as shown in Figure 6.4. Consider the *ShoppingCentre* feature domain as an example (see the highlighted instance at the top left corner in Figure 6.4). Its initial properties only include a data property showing its domain code as '02' and an object property showing it has a super class as 'RetailOutlet' (following the red arrow from *ShoppingCentre* feature domain). The class-subclass relationships enable *ShoppingCentre* links to *RetialOutlet* feature subtype and *CommerciaoPOI* feature class (followed the blue arrows).

The SWRL rule below the instances' property assertions is making use of the known properties of *ShoppingCentre*, *RetialOutlet* and *CommercialPOI*, and their

[70] https://protegewiki.stanford.edu/wiki/OntoGraf

relationships to infer unspecified properties for ShoppingCentre. The body part (before arrow) of the SWRL is understood as "if a POI domain (*ShoppingCentre*) is a subclass of a subtype (*RetialOutlet*), and the subtype (*RetialOutlet*) is a subclass of a class (*CommercialPOI*), the subtype code (*RetailOutlet's*) and the class code (*CommercialPOI's*) are known", then the head part (after arrow) of the SWRL can infer "the POI domain (*ShoppingCentre*) also has a subtype code (same as *RetailOutlet*'s), a class code (same as *CommercialPOI*'s) and a classification code (concatenation of class code, subtype code and its domain code)".

After running the reasoner, the property assertions are increased for *ShoppingCentre* domain. All properties highlighted in yellow are inferred by the rule and its inferred classification code is inside the red rectangle (see the bottom part of Figure 6.4). The rule together with all classes, instances for each class, object property and data properties presented are considered as the top-level ontology for Points of Interest (Figure 6.4). The Top-level ontology includes the minimum information required to express the essential knowledge in this POI study area.

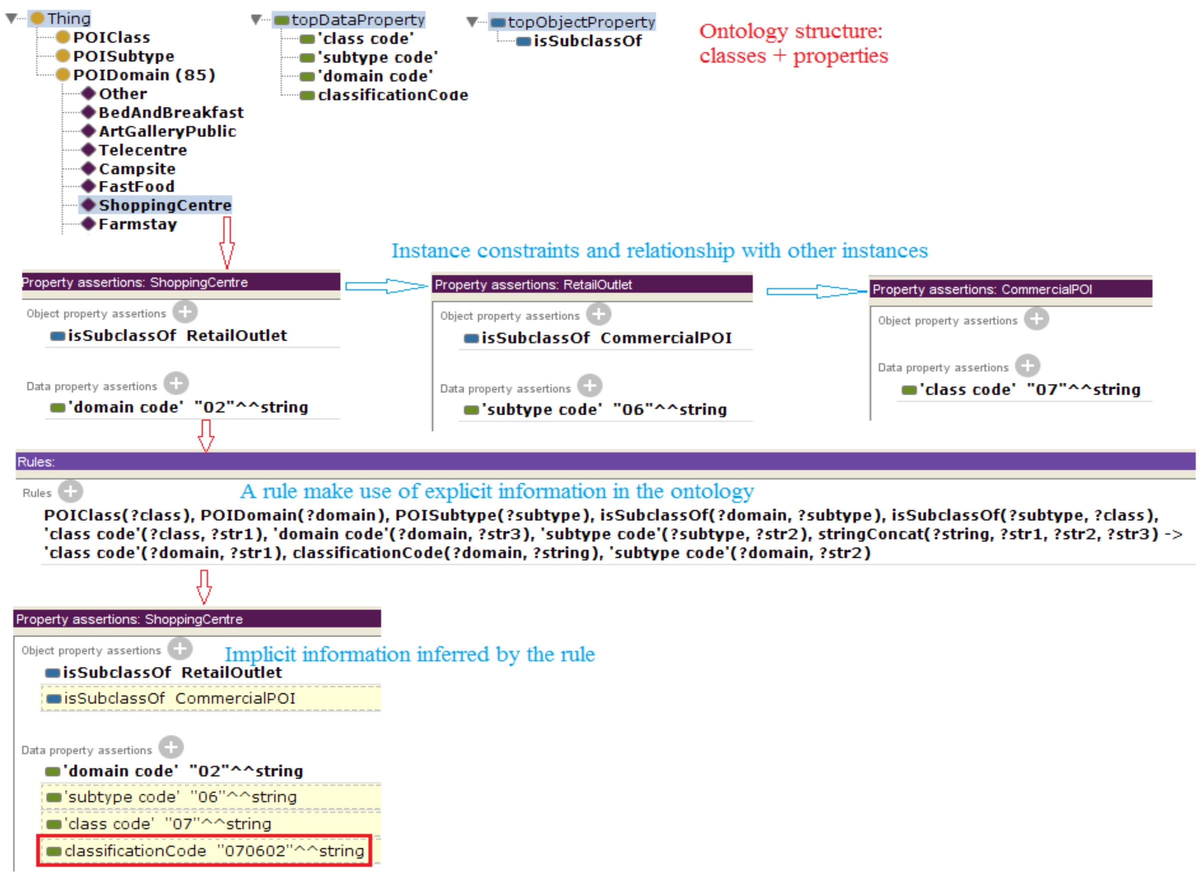

Figure 6.4 POI top level ontology

6.3.2 Stage 2: Data Conversion and Alignment

When dealing with a specific project or application, the top-level ontology can be expanded to accommodate specific business needs. For example, the data property and object property lists are expanded so they can be used to transform the source data into RDF triples and used in reasoning processes (Figure 6.5).

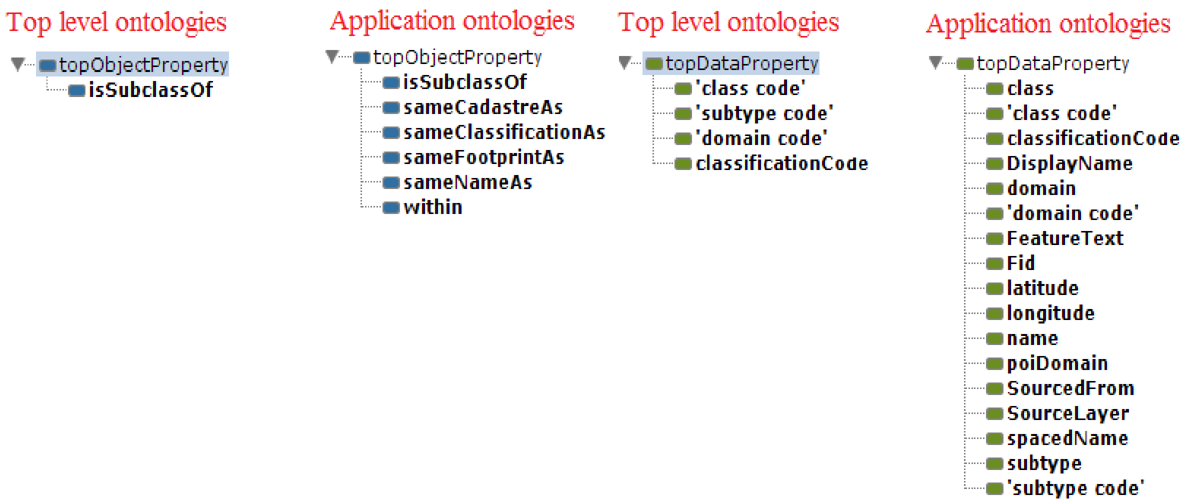

Figure 6.5 Developed application ontology based on top level ontology

The three source datasets have quite different schemas including different levels of granularity (see Figure 6.6). For example, even though the classification system for the POI was adopted by each source they represent it differently. The WAPOL dataset has three columns recording the POIs' feature class, feature subtype and feature domain values while DFES only contains the feature domain. The Landgate dataset has six digital numbers to present the classification code. In order to automatically compare if two POIs are in the same category, they need to all have the same attribute, either the feature domain value or classification code.

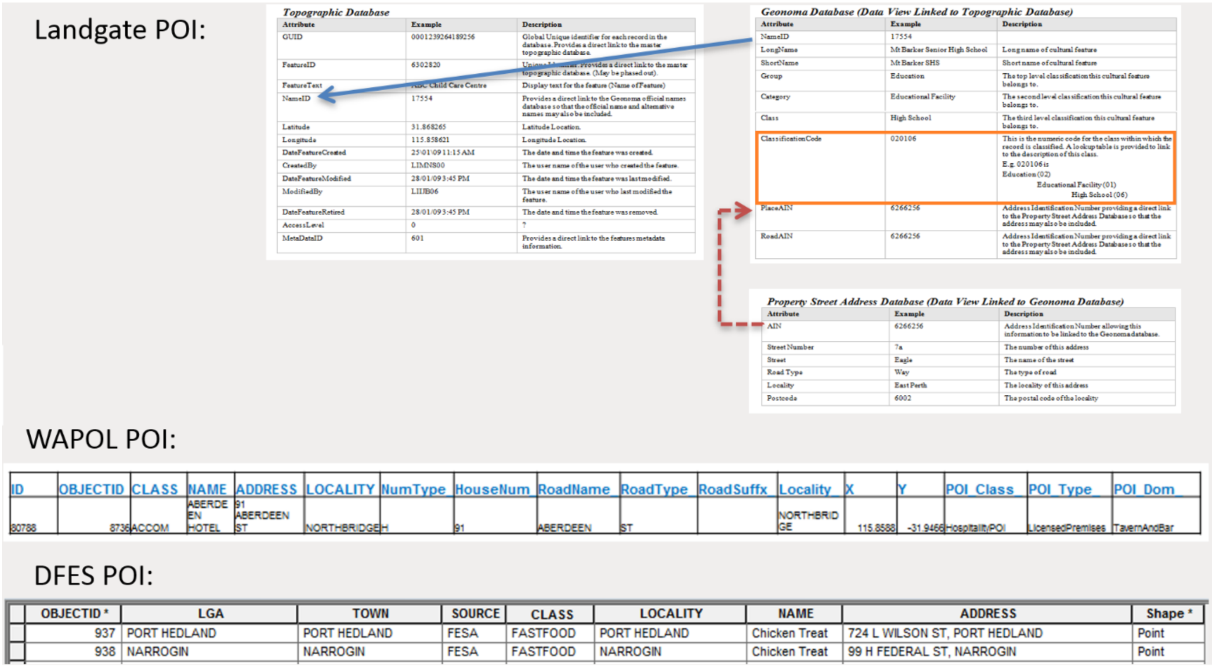

Figure 6.6 Respective data schema of three source datasets

SWRL rules are used to read in the different kinds of classification attributes from each source and infer the missing information contained in the POI classification system so they can have the same attribute granularity. In the top-level ontology (Figure 6.4), the 6-digit classification code has already been inferred for each feature domain. Hence, for example, if a POI has a feature domain as “ShoppingCentre”, its classification code can be retrieved from the ontology via a SWRL rule as well. This is because data is linked to the ontology during the RDF conversion process and therefore the data has the same semantic description as the ontology. Conversely, if a POI classification code is known, the relevant classification information can also be retrieved by a rule. The rules are shown in Figure 6.7. Reading from top to bottom in Figure 6.7;

- The first two SWRL rules are targeting the WAPOL source and DFES source data, respectively; in which only the POIDomain value is known and none of the code values are known.
- The third SWRL rule is targeting Landgate source data in which the classification code is known but the POIDomain value and three 2-digit codes are unknown.

After running the reasoner, properties (shown in yellow see bottom part of Figure 6.7) are inferred by the rules; while the other data properties are drawn directly from

RDF conversion. After alignment, the three example POIs shown below have the same attribute granularity.

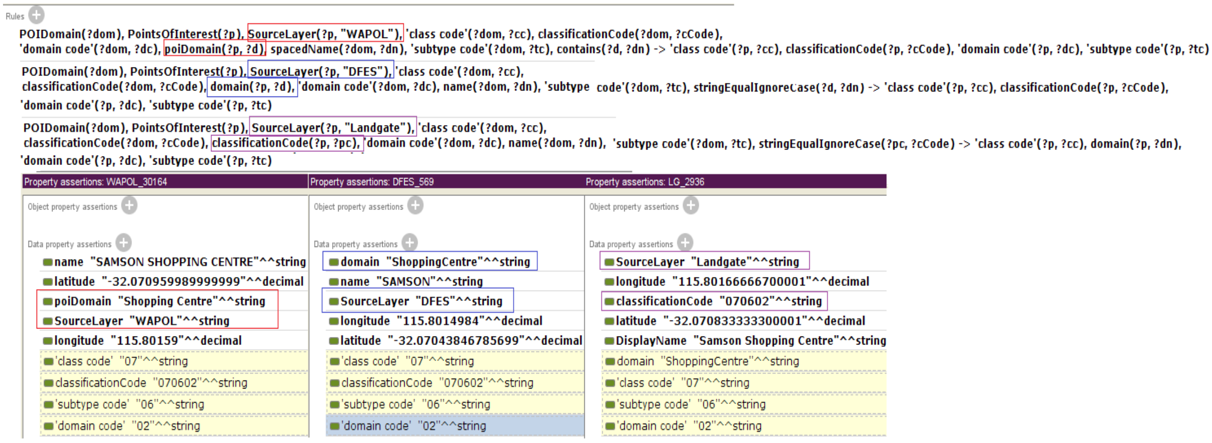

Figure 6.7 Using SWRL rules to align disparate attributes

6.3.3 Stage 3 & Stage 4: Finding POI Matches and Attribute Conflation

The logic of finding matches and conflation is as follows:

(a) Search points in buffer zone: The spatial (geographic location) characteristic is used as the first step in finding matches. For a selected POI, a buffer size is defined and used to calculate the distance between the POI and its surrounding POIs. Only points that fall inside the buffer zone of the selected point will be considered for conflation. This is because points located closer are more likely to be the same point than those further away. Buffer is a common geoprocessing which can easily be handled by GIS applications, so rule is not used for this step.

(b) Compare classification code (Rule 1): the second step takes advantage of the POI classification system. As shown in Figure 6.1, shopping centre, supermarket, fast food, bus station and taxi rank, could all cluster within a buffer zone. However, each belongs to a different feature domain in the POI classification system so their classification code is different. Only points with the same classification code as the selected POI are considered potential matches to be used in the next comparison step.

(c) Compare by name string (Rule 2): For example, even though all POIs may belong to the Fast-food feature domain, a POI named McDonalds® and another one named KFC® must not be conflated into a single POI because they represent different fast food stores. Following the classification code comparison, the matching list is further narrowed down by doing a name string measure. A POI named “KFC Cannington” and “Kentucky Fried Chicken Cannington” will be the matched points and a POI named “McDonald’s Cannington” will not be in the matched list.

Up to this point the matching and linking process is finished and a list of candidate POIs is ready to be conflated. The list normally contains two or three points, so the next step is to decide which point to keep.

(d) Interrelated Relationships (Rule 3 & Rule 4): During the conflation stage, human intervention is normally required as human logic is currently more efficient than comparison algorithm logic. Human experts can use other reference data to decide which one is the best. In this case, cadastral boundary and building footprint datasets are used as reference data. The reason is because of the topological relationship they have with POI data. A building footprint must fall into a cadastre boundary, and if a point represents that building, theoretically it must fall into the footprint too. The point is less accurate if it is outside of the footprint but inside the cadastre boundary. It is even less accurate if it is outside the cadastre boundary. Using this logic, if only one point is within the building footprint, then it is considered the most accurate point. This is the point kept and the other physical points will be removed, and their attributes conflated into this point. The next choice is the single point within the cadastral boundary.

(e) User purposes (Rule 5): In the situation where there are still multiple points within the building footprint or none inside the footprint but more than one inside the cadastre boundary, experts usually decide which point to keep based on different purposes and these purposes can be formulated into rules. There are three rules generated:

   (i) Provenance and Metadata Rule: The order of reliability is determined by the combined information of metadata and interviews across agencies’ experts. In the case study, the order is Landgate, WAPOL, and then DFES. When this option is selected, the assumption is that users want to decide based on the agency's authority.

   (ii) Statistical Rule: The centroid (mean location) of all the points in the candidate list determines the conflated point. The assumption for selecting this option is when all data from the various sources is to be treated equally.

(iii) Random Rule: Randomly select a point within the candidates list. The reason for selecting this option is when the location does not need a high level of accuracy, for example, for general navigation purposes.

According to the above logic, rules generated run in a sequential order, i.e. the result of the previous rule will be used as a condition in the following rule, showcased in Figure 6.8. This method demonstrates a chain of rules to deal with the situation where multiple POIs are within a building footprint, the user making a final decision based on *Provenance & Metadata rule* (Rule 5) and the result is output to a new class named *ConflatedPoint*.

The first rule in Figure 6.8 is comparing the classification codes between any two POIs (?p1 and ?p2) that returned from the buffer calculation, if the two codes are identical (*stringEqualIgnoreCase(?cCode1,?cCode2)*), then both POIs have an inferred property indicates their classification codes are the same (*sameClassificationAs (?p1,?p2)* and *sameClassificationAs(?p2,?p1)*). The inferred results are carried into next rule.

Rule No.2 compares name strings of two POIs (*name(?p1,?n1)* and *name(?p2,?n2)*) that have same classification codes. If the two name strings are the same (*stringEqualIgnoreCase(?n1,?n2)*), then they are returned another inferred property (*sameNameAs(?p1,?p2)*). The result is used in next rule.

Rule No.3 is looking for POIs within a same cadastre boundary (*withIn(?p1,?c1)* and *withIn(?p2,?c1)*), then they have an inferred property *sameCadastreAs(?p1,?p2)*.
From the result of Rule No.3, Rule No.4 further filters POIs and only keeps those are within a same building footprint (the inferred property is *sameFootprintAs(?p1,?p2)*) based on conditions *within(?p1,?fp1)* and *within(?p2,?fp1)*.

The last rule in Figure 8, Rule No.5 is checking which POI has a source from "Landgate", then the POI that fulfils the condition (*stringEqualIgnoreCase(?s1,"Landgate")*) is the one kept as conflated result (*ConflatedPoint(?p1)*).

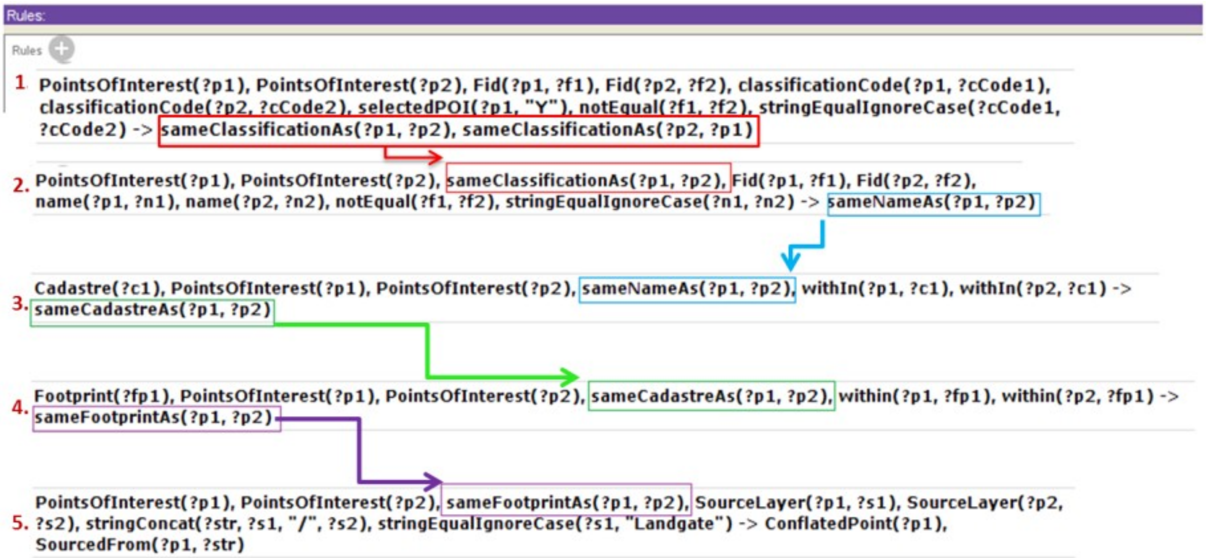

Figure 6.8 Rule Chain for finding the best location based on Provenance & Metadata Rule

6. 4 Evaluation

6.4.1 Preliminary Testing

The methodology presented was tested with an example scenario shown in Figure 6.9 and the process was run in Protégé. A POI from the WAPOL dataset was selected (the blue point inside the basket icon) and a 250-metre buffer around the point was calculated. Five points from Landgate, five points from WAPOL and one point from DFES, as shown in yellow, blue and purple, respectively, fall within the buffer zone. The selected POI representing a shopping centre and its corresponding POIs are one from DFES located in a roundabout and one from Landgate which is located within the building footprint (represented by the green polygon). According to the conflation logic in Section 6.3.3, these three POIs will be conflated into a single point by taking the POI location from the Landgate dataset, shown using the star marker in Figure 6.9.

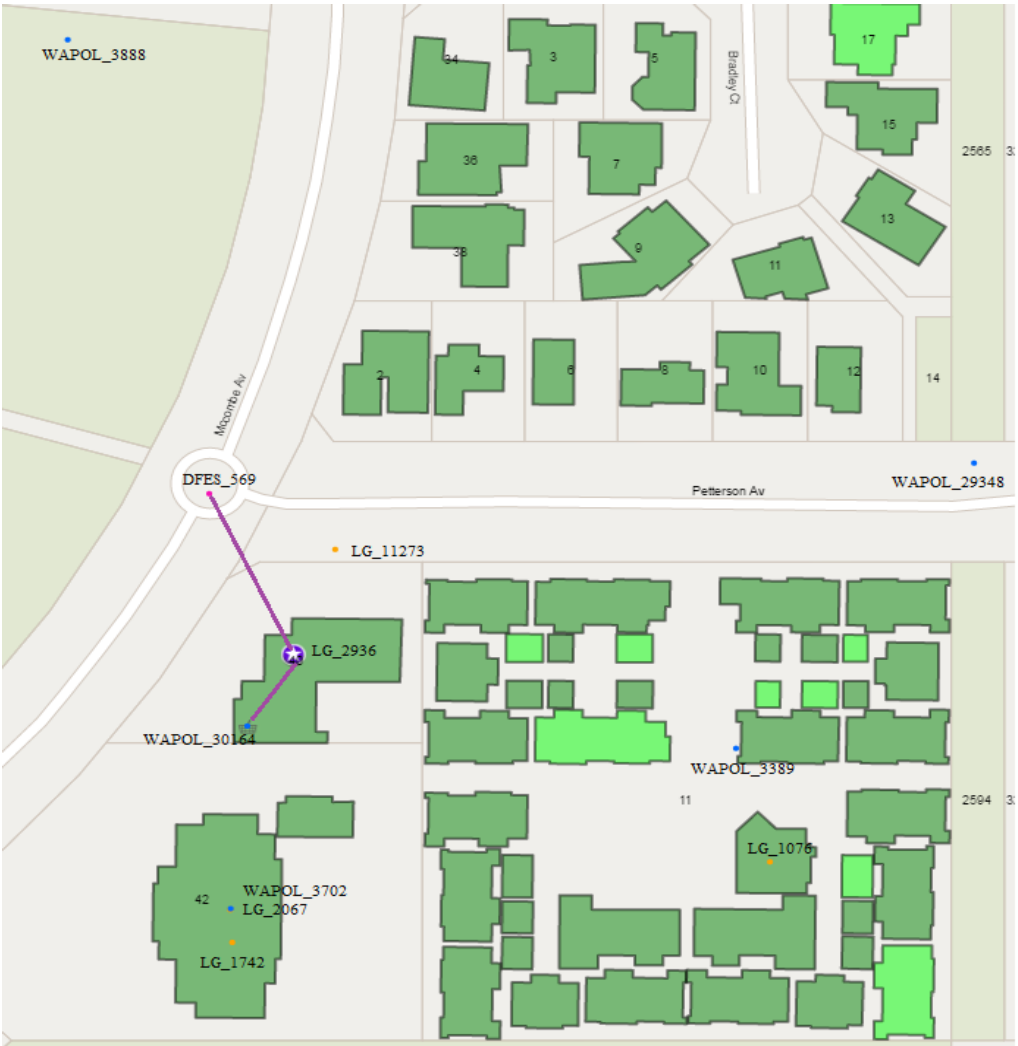

Figure 6.9 Example scenario

All points in the example scenario and their relevant attributes used in the reasoning processes are listed in Figure 6.10. These POIs were added to the same file as the designed POI ontology and SWRL rules so they could be run together with the Protégé reasoner. Calculating distances for buffers uses mathematical functions conducted outside Protégé. Comparing POIs with the digital cadastre and the building footprints are also pre-determined by other methods, such as layer intersection outside Protégé. The intersection results listed in Figure 6.10 shows whether a POI is "within" a cadastral boundary or a building footprint (blue columns). The yellow columns represent data properties and the blue columns show the object properties.

		poiDomain	domain	classification code	name	DisplayName	FeatureText	Fid	logitude	latitude	SourceLayer	within	within
selected POI	WAPOL_30164	Shopping Centre			SAMSON SHOPPING CENTRE			191	115.801590	-32.070960	WAPOL	cad1	fp1
in Buffer Zone	WAPOL_29348	Park Reserve			OWEN FITZGERALD PARK SAMSON			23864	115.803330	-32.070370	WAPOL		
	WAPOL_3389	Park Reserve			SAMSON GARDEN PARKLANDS			24372	115.802760	-32.071010	WAPOL		
	WAPOL_3702	Community Centre			SAMSON RECREATION CENTRE			28609	115.801550	-32.071370	WAPOL	cad2	fp2
	WAPOL_3888	Toilet			SIR FREDERICK SAMSON RESERVE PUBLIC TOILET			28688	115.801160	-32.069420	WAPOL		
	LG_2936			070602		Samson Shopping Centre		34	115.801667	-32.070833	Landgate	cad1	fp1
	LG_2067			050201			SAMSON RECREATION CENTRE	1784	115.801549	-32.071372	Landgate	cad2	fp2
	LG_1742			070700			WANSLEA SAMSON OUTSIDE SCHOOL HOURS CARE	1578	115.801554	-32.071445	Landgate	cad2	fp2
	LG_11273			050102			SAMSON PUBLIC TELEPHONE	10120	115.801800	-32.070564	Landgate		
	LG_1076			070800			GARDEN PARKLANDS	1047	115.802842	-32.071265	Landgate	cad3	fp3
	DFES_569		ShoppingCentre		SAMSON			99	115.801498	-32.070438	DFES		

Figure 6.10 Attribute list of example scenario POIs

The Protégé built-in reasoner Pellet[71] is run to check whether it can return correctly inferred results for different POIs by each rule. As shown in Figure 6.9, *DFES_569*, *LG_2936* and *WAPOL_30164* are supposed to be conflated into one, i.e *LG_2936*. The inference results of the three POIs are shown in Figure 6.11.

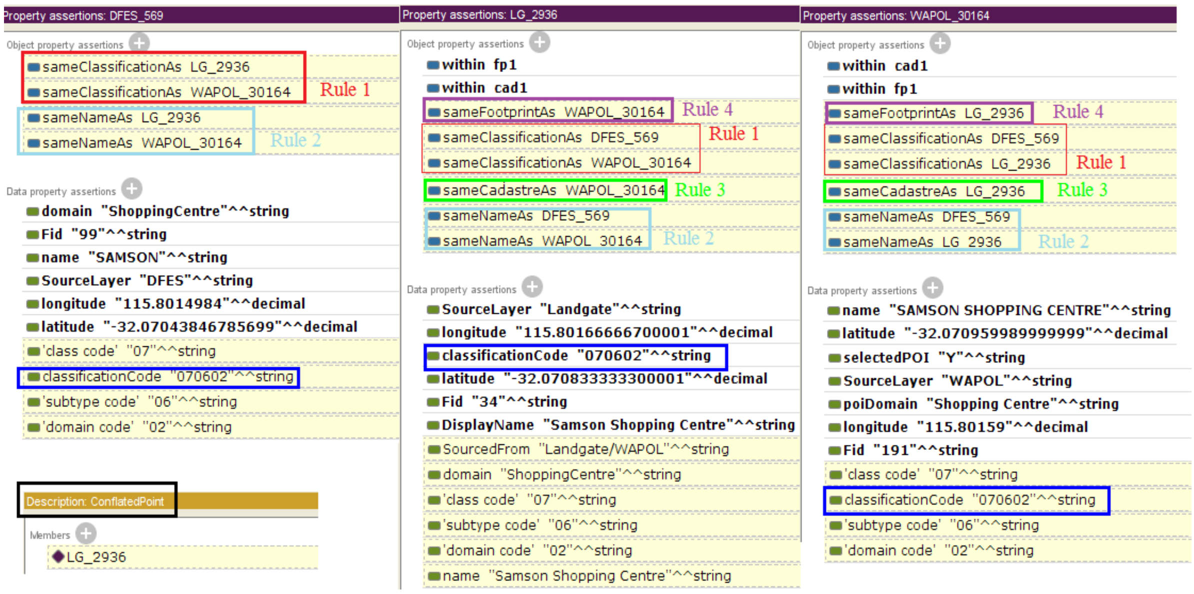

Figure 6.11 Properties for POIs after running reasoner

[71] Pellet is an open-source Java based OWL 2 reasoner. https://www.w3.org/2001/sw/wiki/Pellet

(a) Rule 1 returns results for the three POIs (see red rectangle). It correctly identifies one POI has the same classification code as the other two because they are all "070602" (see dark blue rectangle).

(b) Rule 2 also correctly returns inferred results for each POI. (See light blue rectangle). Each POI has the same name as the other two because the name values are "SAMSON", "Samson Shopping Centre" and "SAMSON SHOPPING CENTRE", so they are either an exact match when ignore case (e.g. "Samson Shopping Centre" and "SAMSON SHOPPING CENTRE") or one is contained in the other one (e.g. "SAMSON" and "SAMSON SHOPPING CENTRE").

(c) Rule 3 and Rule 4 do not return any result for *DFES_569* because it is not within any cadastral boundary or building footprint. Both rules return a result for the other two POIs because they all within "cad1" and "fp1", so they have *sameCadastreAs* and *sameFootprintAs* with each other.

(d) Rule 5 returns the final result as *LG_2936*, which is an inferred member of *ConflatedPoint* class (see black rectangle in the lower left corner). This is the expected result for the test scenario based on the *Provenance & Metadata Rule*, i.e. Landgate data is more accurate than WAPOL data when two POIs from these two sources are both within a building footprint.

The inferred results for other points included in the test scenario are shown in Figure 6.12. Because their classification codes are different (see the classification codes within orange boxes) from the selected POI's (i.e. *070602*), no results are generated in Rule 1 hence they are not carried any further in the reasoning processes. This fulfils the expectation of the rules as only those candidates that meet the previous rules are carried into the next rule.

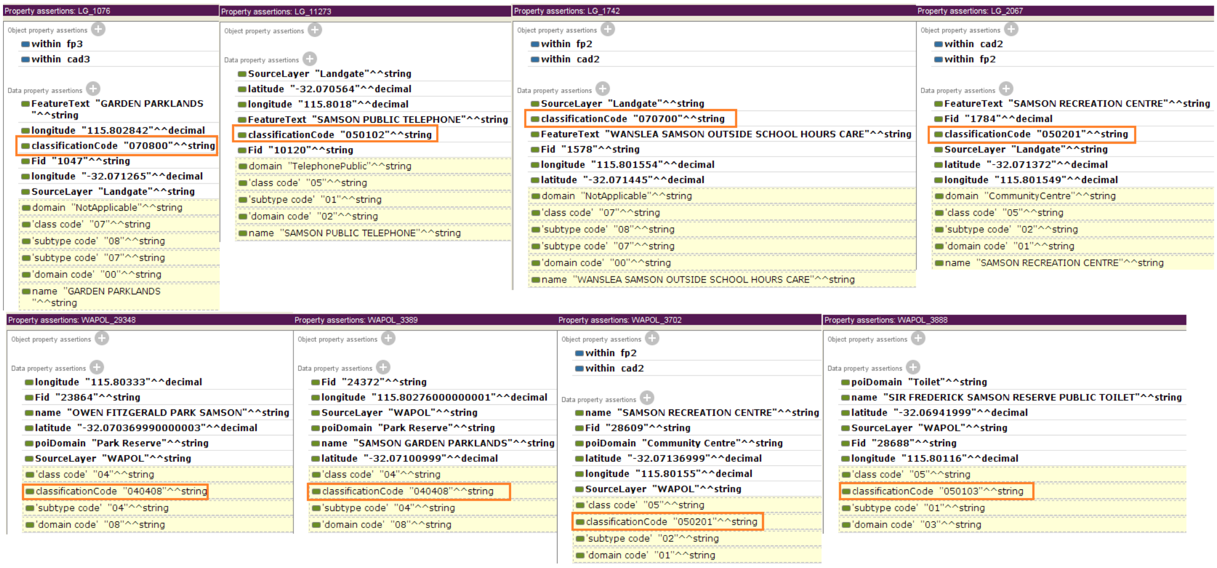

Figure 6.12 Reasoning results for all other points

6.4.2 Further Evaluation

The preliminary testing results demonstrate that the SWRL Rule-based Data Conflation methodology can model domain experts' decision-making logic thus enabling geospatial data to be conflated automatically. However, as Protégé is essentially an ontology and SWRL rule editor, there are many functions that cannot be performed, such as, calculate points within buffer zone, and intersect points with reference layers. Also, the example only demonstrates one scenario, which is two points within the same footprint and the final decision is based on the Provenance and Metadata Rule. However, there could be many other situations as well, such as a decision made by statistical rules or random rules, or if only one point is in a footprint, the point can be chosen automatically etc.

A Proof of Concept (PoC) [72] web portal was thus developed so it can better integrate the aforementioned functions and can use different rules to deal with different situations. As the PoC web portal is capable of dealing with larger datasets and more complicated scenarios, a further evaluation was able to be performed. The evaluation is based on conflating ShoppingCentre feature domain points from the three sources

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[72] https://gateway.amristar.com/automatedconflation/#/?_k=wpgbj8; username: **crcsi** ; password: **l@ndg@te**

including 351 POIs from Landgate, 255 POIs from WAPOL and 381 POIs from DFES. These POIs are well distributed across the Perth Metro area.

The reason for using this particular feature domain, is that these points exist in all three datasets in the study area. The WAPOL dataset and Landgate dataset cover most of the feature domains, while the DFES dataset only records FastFood, Supermarket and ShoppingCentre feature domains. However, the Landgate dataset does not contain enough samples in the FastFood and Supermarket feature domain with only 8, and 28 points in each feature domain. Furthermore, these two feature domain points in the Landgate dataset are far away from the Perth Metro area and no building footprint data is available for comparison. Therefore, ShoppingCentre feature domain data in this case is the most appropriate test data to evaluate whether conflation decisions can be correctly made among the three sources.

The buffer size is set as 250 metres because it is sufficient to return relevant points as manually checked on several big shopping centres in the metropolitan area and it is not too big to decrease system performance. However, in the PoC web portal users are able to decide what buffer to use in their search area of interest.

The building footprints and cadastral boundaries reference datasets are provided by Landgate, which is the recognised authoritative source.

6.4.3 Evaluation Criteria and Results

The evaluation focuses on two aspects; (a) whether the system can effectively reduce duplicate data; and (b) the accuracy of the conflated results.

(a) In terms of duplication, the number of conflated POIs is 493, whereas the number of POIs from the combined datasets is 987 (Figure 6.13). This means that over half of the points are duplicated, and hence have been removed. At the same time, in comparison to each of the original datasets, the conflated dataset has increased the number of valid POIs and thus improved the data coverage. This is shown in Figure 6.13 where compare to Landgate, the conflated dataset has increased the number of valid POIs by 40%, to WAPOL by 93% and to DFES by 29% respectively.

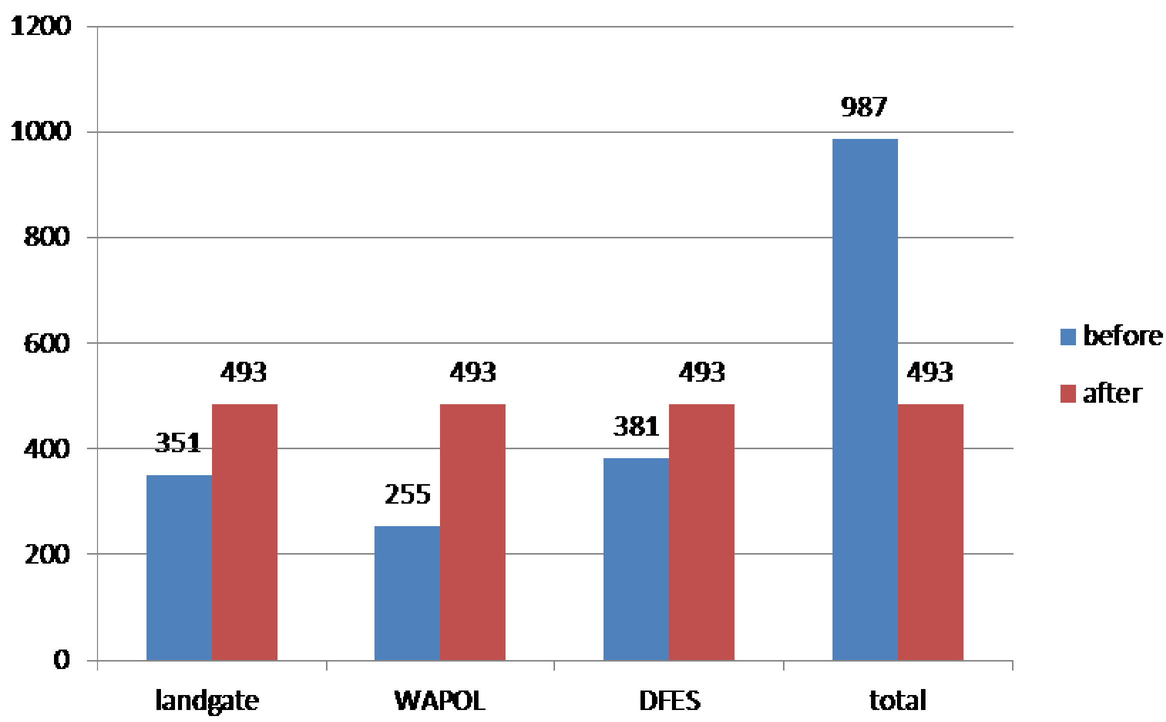

Figure 6.13 Number of points before and after conflation for each source

(b) In order to examine the accuracy of the conflation results, manual validation was performed. Among the 493 conflated POIs, 283 points were generated from multiple points, i.e. either from more than one source or more than one point from the same source. The conflated results are downloaded in the shapefile format and loaded into ArcMap. Each of these 283 points were overlaid with the three source datasets and the two reference datasets to check whether or not the SWRL rule system effectively selected the best location for each scenario. For instance, the analysis of conflation result for the scenario shown in Figure 6.9 is recorded in Figure 6.14. (highlighted in green). Examples in Figure 6.14. show how many source points were involved in conflating each point, whether or not source points are within reference boundaries and whether the conflated point is automatically selected because only one point is left in the reference boundary or decided by the rule if multiple source points are within the reference boundary. A full list of records can be seen from Appendix B.

number of points within footprint
number of points within cadastre
number of points not within any reference boundary
'F' means automatically select the only point within footprint or 'C' means select the only point within cadastre
number of source points involved

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
MOSMAN HEIGHTS/ MOSMAN HEIGHTS SHOPPING CENTRE	112-114 WELLINGTON STREET, MOSMAN	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
QUINNS VILLAGE SHOPPING CENTRE/ QUINNS VILLAGE	121 QUINNS ROAD, QUINNS ROCK	3	1	1	1	F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint WAPOL in cadastre, DFES out on road, auto-select
STOCKLAND BULL CREEK/ STOCKLAND BULLCREEK	CORNER SOUTH STREET & BENNINGFIELD ROAD, BULL CREEK	2	1		1	F		LG	LG	6	Y(same point, but bit complicate to be conflated)	Source from DFES&LGL, LG in footprint , DFES out on road, auto-select
GLENDALOUGH VILLAGE	2-4 JON SANDERS DRIVE, GLENDALOUGH	2	2				LG		LG	6	Y(same point, but bit complicate to be conflated)	Source from DFES&LGL, both in footprint , decided by rule
THOMSON BAY SETTLEMENT SHOPS	, ROTTNEST ISLAND	2	2				LG		LG	5	Y(? Address not complete)	2 points from LG, in different footprint, not sure how to decide between the two
SAMSON/ SAMSON SHOPPING CENTRE/ SAMSON SHOPPING CENTRE	40 MCCOOMBE AVENUE, SAMSON	3	2		1		LG		LG	6	Y	Source from DFES&LG&WAPOL, LG&WAPOL in footprint, DFES out on road, decided by rule
DARLING RIDGE SHOPPING CENTRE/ DARLING RIDGE	309 MORRISON ROAD, SWAN VIEW	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule

Figure 6.14 Analysis record for conflated points

The statistical analysis revealed that 88 points were conflated automatically because there was only one data source with the point inside the building footprint. There are six cases where no points were within a building footprint and only one point inside cadastre boundary. The remaining 189 conflated points were decided by the *Provenance and Metadata Rule* as multiple source points existed in a same footprint or cadastral boundary. As the *Provenance and Metadata Rule* define the Landgate dataset is the most accurate, the result showing 156 points from Landgate source followed by 24 points from WAPOL and 9 points from DFES fulfils the expectation. The statistical results are displayed in Table 6-1.

Table 6-1. Evaluation result for conflate three datasets

<table>
<tr><th rowspan="4">Source</th><th colspan="4"># Conflated POI</th><th rowspan="4">Total</th></tr>
<tr><th colspan="3">#Multi-sources</th><th rowspan="3"># Single source</th></tr>
<tr><th colspan="2">Auto-select</th><th rowspan="2">Decided by rule</th></tr>
<tr><th>In footprint</th><th>In cadastre</th></tr>
<tr><td>Landgate</td><td>58</td><td>2</td><td>156</td><td>60</td><td>276</td></tr>
<tr><td>WAPOL</td><td>15</td><td>4</td><td>24</td><td>63</td><td>106</td></tr>
<tr><td>DFES</td><td>15</td><td>0</td><td>9</td><td>87</td><td>111</td></tr>
<tr><td>Total</td><td>88</td><td>6</td><td>189</td><td>210</td><td>Total: 493</td></tr>
</table>

6.4.4 Discussion

Among the 283 conflated points, only five points were identified as incorrect. Three of them related to the incorrect name string matching results, and the other two are due to the candidate points being too close to the cadastre/building footprint boundaries, so the point and polygon intersect results are incorrect. Therefore, the conflation accuracy for *ShoppingCentre* POI is 98%.

There are 210 points in the conflated dataset, which were derived from a single source. However, 64 of these points should have matched other points but were excluded due to the current name string method being too simple. The current string match method is using default SWRL *Built-Ins for String*, so it can only perform simple matches, such as match points with exactly the same name or where one name is contained within another name string. However, some name patterns such as full name (e.g. *Kentucky Fried Chicken*) and acronym name (e.g. *KFC*) will not return a result as matched. A better match method is required to deal with various name patterns across the datasets.

Furthermore, there are some limitations regarding the demonstrated rule chain. Firstly, in order to demonstrate the integrity of the rule chain, only one rule is displayed for comparing name strings (Rule 2 in Figure 6.8). This rule returned *sameNameAs* results for *LG_2936* and *WAPOL_30164* because their attribute values are "Samson Shopping Centre" and "SAMSON SHOPPING CENTRE" respectively, fulfilling the string-matching method of *stringEqualIgnoreCase*. In order for another point *DFES_569* to have *sameNameAs* results with *LG_2936* and *WAPOL_30164*, another string comparison rule is used. Everything else is the same except string matching method *containsIgnoreCase* is used instead because its attribute value is "SAMSON". The two string matching methods used in the example are enlisted in the default built-ins for SWRL. They only perform simple comparison between strings that meet the pattern requirement. If the attribute value styles vary, such as position changed (e.g. *Shopping Centre of Samson*) or used some extent of acronym (e.g. *CT* instead of *centre*), then the rules become cumbersome as a rule needed to be created to deal with each situation.

In future work, more sophisticated string match algorithms, such as those developed by (Hastings, 2008; McKenzie, Janowicz, & Adams, 2014; Samal et al., 2004) can be explored to generate custom built-Ins for SWRL to improve the accuracy of the name string match in order to reduce the number of duplicate points further and get a higher match return.

6.4.5 Limitation and Future Works

To the best of our knowledge, using SW technology in geospatial data conflation as described, has not been done previously. So, there is no opportunity for comparison with other systems. Hence the evaluation approach taken in this study is to self-test the model and methods developed. Since the current methods for data conflation are mainly manual, the model is evaluated to determine what extent automated processes can be realised. The resulting accuracy is tested and compared against conflation results achieved using manual methods.

There are limitation regarding to the evaluation as the proposed AGDC system is tested through single case that is successfully conflating three overlapping point datasets into a single one based on different user's needs. More case studies and evaluations needed in the future to test the AGDC system in order for continuouse improvements. Later future work should test the framework not only on conflating other feature classes of POI data but also test datatypes more broadly. For example, test on conflating other kinds of vector datasets with various combination, such as, among the same geometric types (polyline-to-polyline, polygon-to-polygon), or different kinds of geometric types (conflating point datasets with polyline/polygon datasets or conflating polyline datasets with polygon datasets).

Further evaluation is valuable if domain experts can be involved too. As the essential part of the AGDC system is to model domain experts' knowledge and conflation logic through a set of SWRL rules. For future work, a good starting point can be presenting the developed Proof of Concept web portal to spatial domain experts involved in the LOC8WA project and evaluating to what extend the system can meet their expectations. The evaluation feedbacks can help better understanding the problem and further improving the AGDC system.

6. 5 Proof of Concept Web Portal Development

The Proof of Concept (PoC)[73] web portal aims at demonstrating the geospatial data conflation processes that implements the concepts and methods based on Semantic Web technologies proposed in this research. The development of industrial solutions for the agencies is out of scope of this thesis.

6.5.1 Technical Specifications of Proof of Concept

The purpose of the PoC is to visually demonstrate the conflation processes of three disparate WA government agencies' POI data into a single source for a specified purpose. It provides a user experience through an interactive user interface which allows users to define various settings including buffer size, interested feature classes for conflation and the final selection rule that meet their business needs. Other than the three POI datasets provided by Landgate, WA Police and DFES for the conflation purposes, the PoC also leverages on existing Landgate's SLIP datasets (specifically using building footprint and cadastre boundary), Open Street Map (OSM), Bing Imagery and the G-NAF[74] source layers to visually cross-reference POI data. The user interface is built upon Mapworks platform while Protégé and Apache Jena are using behind the scene to build ontologies and execute RDFs to SWRL rules. The components of the PoC portal are listed in Figure 6.15.

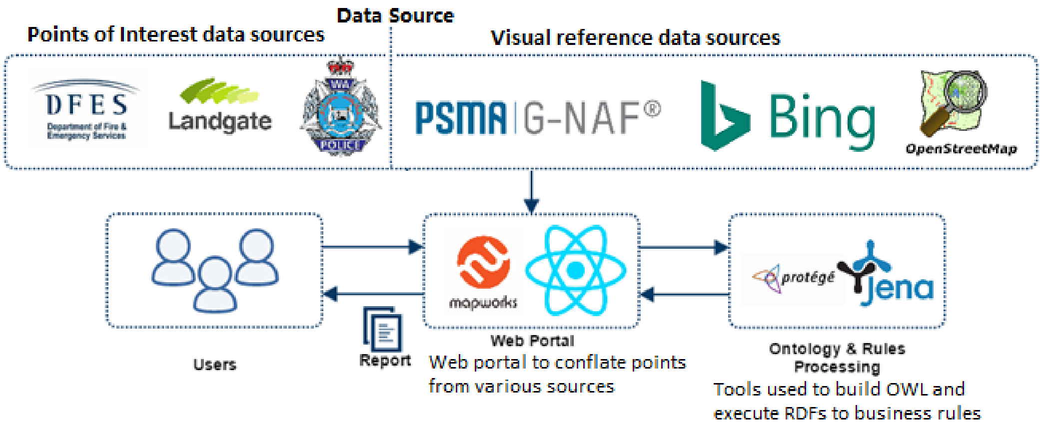

Figure 6.15 Components description[75]

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[73] The development of Proof of Concept (PoC) web portal was facilitated by the CRCSI project developer partner Amristar (https://amristar.com/), and hosted on their infrastructure Mapworks.

[74] PSMA's G-NAF dataset contains all physical addresses in Australia. It's the most trusted source of geocoded addresses for Australian businesses and governments. https://psma.com.au/product/gnaf/.

[75] OSM, Bing Imagery and G-NAF are incorporated into Mapworks platform and used in the PoC as background information for visualisation purpose.

Since the PoC needs to deal with various conflation situations, the SWRL rule chains demonstrated in Figure 6.8 of Section 6.3.3 are further developed to cater for different scenarios and to execute specific tasks such as the name string match discussed in the Section 6.4.4. When inferring whether two POIs have the same name, different SWRL rules are used to cope with different situations, see Figure 6.16 for example. A list of SWRL rules implemented in the PoC web portal can be seen from Appendix C.

II. Infer whether two POIs have the same name:

8. Compare two POIs, if their feature ID are different, but Name string is equal when ignore case, infer them has same name:

PointsOfInterest(?p1), PointsOfInterest(?p2), Fid(?p1, ?f1), Fid(?p2, ?f2), iName(?p1, ?n1), iName(?p2, ?n2), notEqual(?f1, ?f2), stringEqualIgnoreCase(?n1, ?n2) -> sameNameAs(?p1, ?p2)

9. Compare two POIs, if their feature ID are different, the iName are not empty, when ignoring case, one string contains the other, infer them has same name:

PointsOfInterest(?p1), PointsOfInterest(?p2), Fid(?p1, ?f1), Fid(?p2, ?f2), iName(?p1, ?n1), iName(?p2, ?n2), notEqual(?f1, ?f2), notEqual(?n1, ""), notEqual(?n2, ""), containsIgnoreCase(?n1, ?n2) -> sameNameAs(?p1, ?p2)

10. Compare two POIs, if their feature ID are different, the iName are not empty, when ignoring case, one string contains the other, infer them has same name:

PointsOfInterest(?p1), PointsOfInterest(?p2), Fid(?p1, ?f1), Fid(?p2, ?f2), iName(?p1, ?n1), iName(?p2, ?n2), notEqual(?f1, ?f2), notEqual(?n1, ""), notEqual(?n2, ""), containsIgnoreCase(?n2, ?n1), -> sameNameAs(?p1, ?p2)

Figure 6.16 Rule examples implemented in PoC web portal

The entire automated geospatial data conflation workflow of PoC web portal is displayed in Figure 6.17.

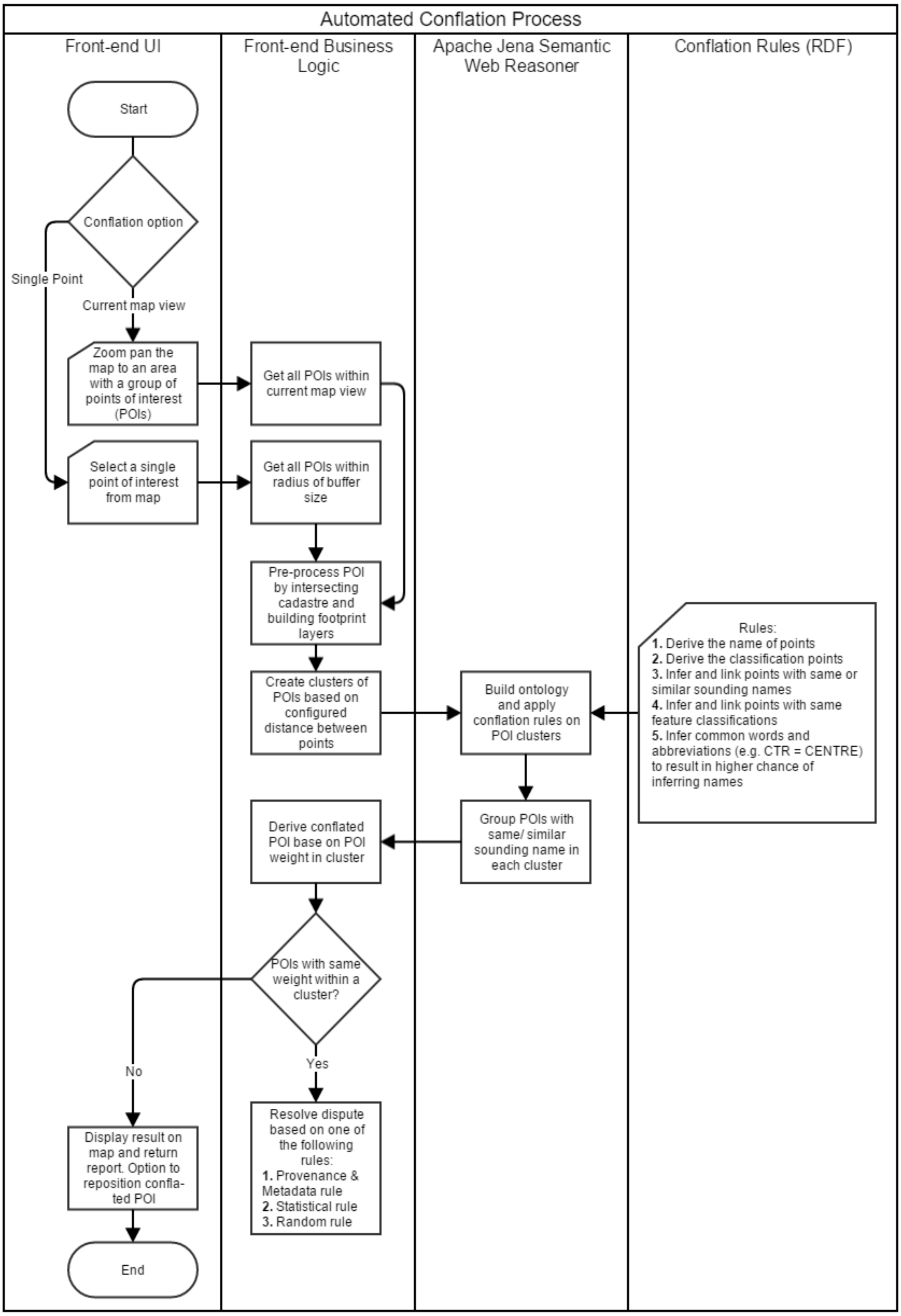

Figure 6.17 Conflation process flow

The PoC portal provides users with two options that either conflate points of interest in the current map view or from a single point of interest.

(a) Conflating points of interest in the current map view

In this use case, the user zooms and/or pans to a location on the map to conflate all the points of interest in the current map view. The maximum number of points of interest to conflate in a single map view is set to a maximum of 1000 geographic points. To improve performance, points are grouped in clusters based in distance and each cluster is conflated individually.

Users would use this feature when they are interested in conflating a group of points of interest in an area (e.g. suburb, LGA, etc.). Before initiating the conflation process, it is mandatory to first define up to 10 feature classes and the data sources to conflate. For example, if the user selects feature class “Fast Food” and “Café and Restaurant”, only points with these selected feature classes will be considered for conflation.

(b) Conflating points of interest from a single point of interest

In this use case, the user selects a point of interest on the map to conflate with other points within a certain distance (buffer size) from the selected point. Before initiating the conflation process, it is mandatory to configure the buffer size and data sources to conflate. There is no need to define what feature classes to conflate as only points of interest with the same feature class as the selected point will be considered for conflation.

6.5.2 Proof of Concept User Interface

The developed Data Conflation PoC[76] web portal provides a visualisation interface so that users can view the dataset points before and after conflation, see Figure 6.18 for an example. The visualisation layer is developed using ReactJS[77] so users are able to access it through a common web browser such as Chrome and Firefox etc.

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[76] https://gateway.amristar.com/automatedconflation/#/?_k=wpgbj8; username: **crcsi** ; password: **l@ndg@te**

[77] https://en.wikipedia.org/wiki/React_(web_framework)

The small colored dots in Figure 6.18. are original source points with each color representing different agency’s data and the star shape pins representing conflated points in the vicinity based on the user's conflation settings.

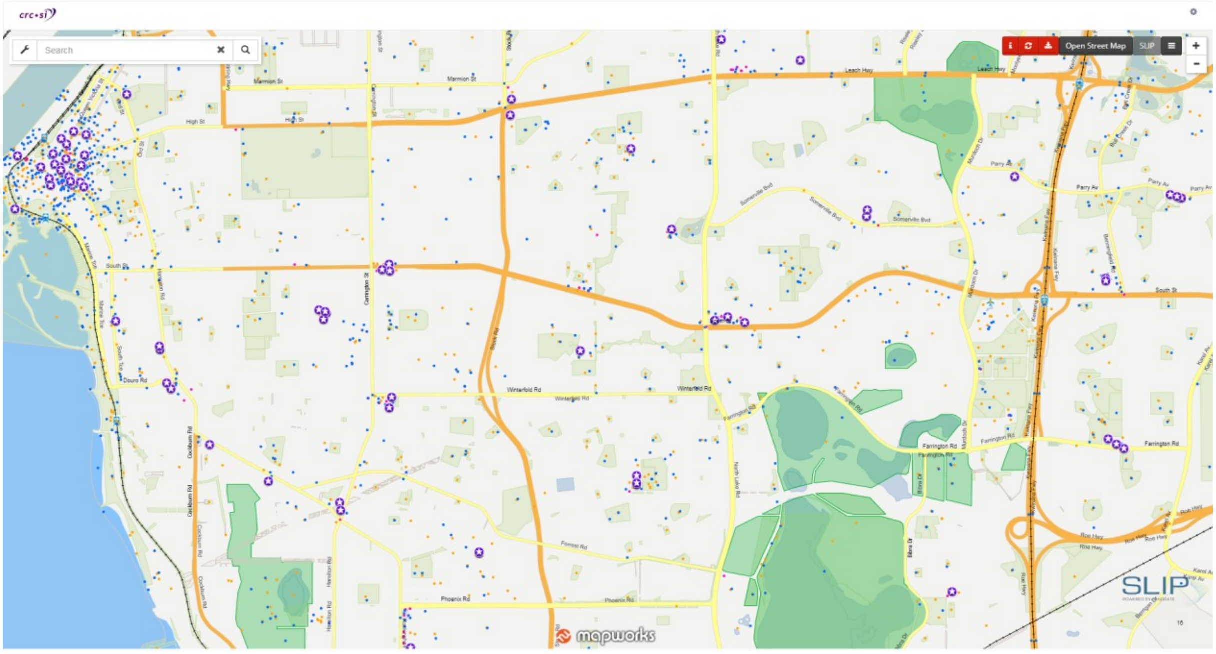

Figure 6.18 Proof of Concept web portal

More visualisation options are available when clicking on the bookmark icon next to the *SLIP* button (see Figure 6.19) where Bing Imagery, GNAF, Cadastre and Building Footprint can be chosen to overlay on top of the background map layer providing visual references. The little red buttons between the Conflate button and the Open Street Map button shown in Figure 6.19 are embedded with two conflation mode options which users can toggle between to choose whether to conflate points of interest by area (i.e. current view window area) or just conflate a single interested point.

Users can click on the little setting icon on the top right corner to activate the conflation setting window. Once activated, a pop-up window will show up and give users options to set up conflation configurations such as buffer size, cluster size, conflation rule and interested feature classes (up to 10 feature classes) to conflate etc. Users can either search for the interested feature class and then select it or browse through the entire feature class list to choose, see Figure 6.20 for options from the settings window.

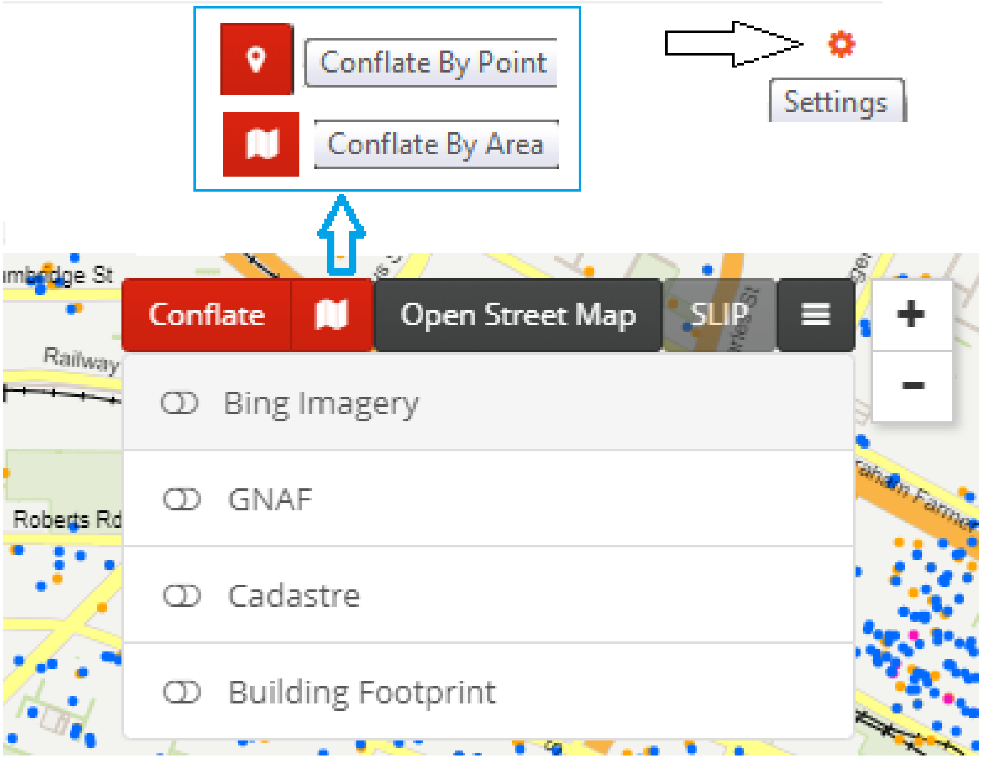

Figure 6.19 User setting options

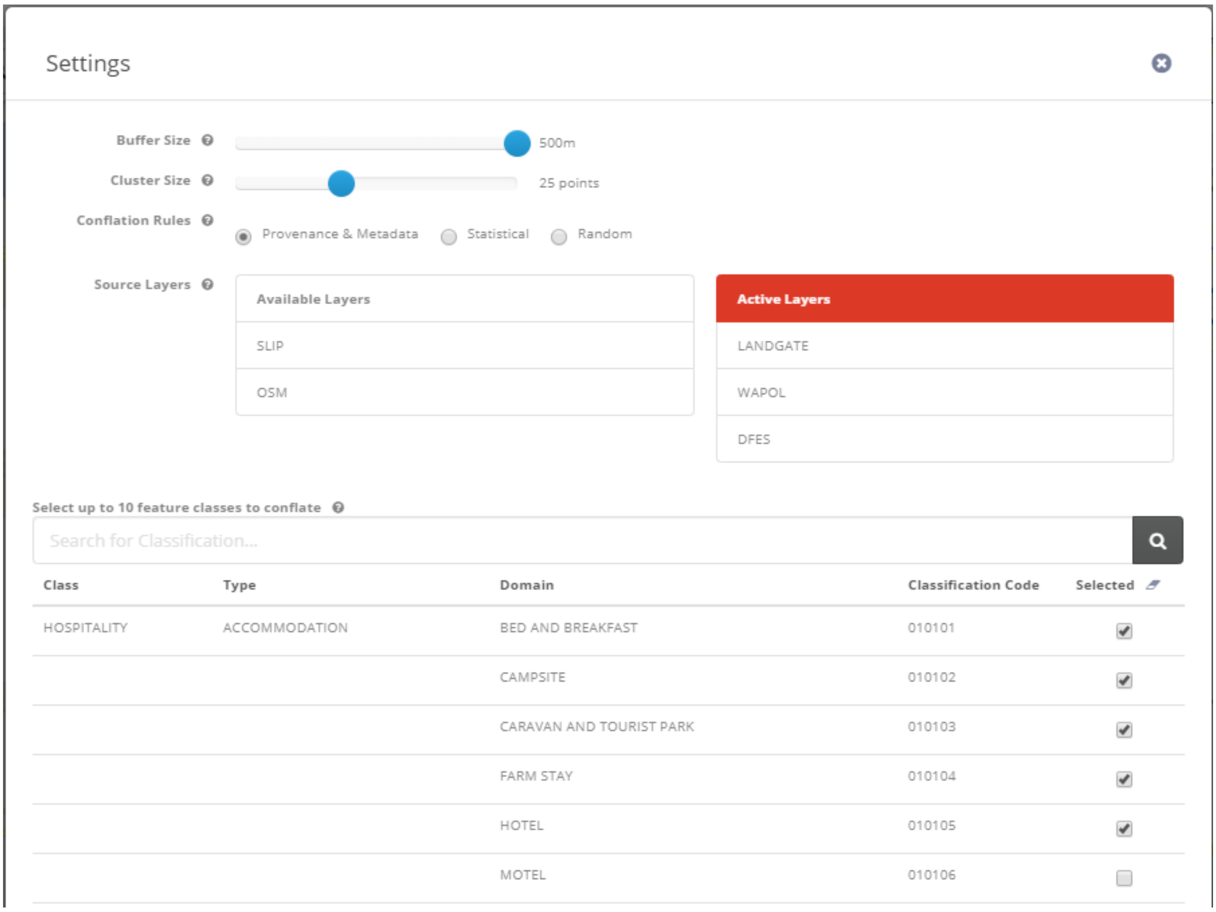

Figure 6.20 Conflation setting window

Once the conflation process has finished, post conflation options are available to users in the top right corner as shown in Figure 6.21. When clicking on the information icon, a statistics summary will appear regarding the conflation processes, such as the total area involved in the conflation processes if the user chooses the conflating by area option, number of conflated points generated in the current conflation and what conflation rule used etc. Other post conflation options include downloading conflated points in shapefile format and clearing the conflation result from the current view if the user is not satisfied.

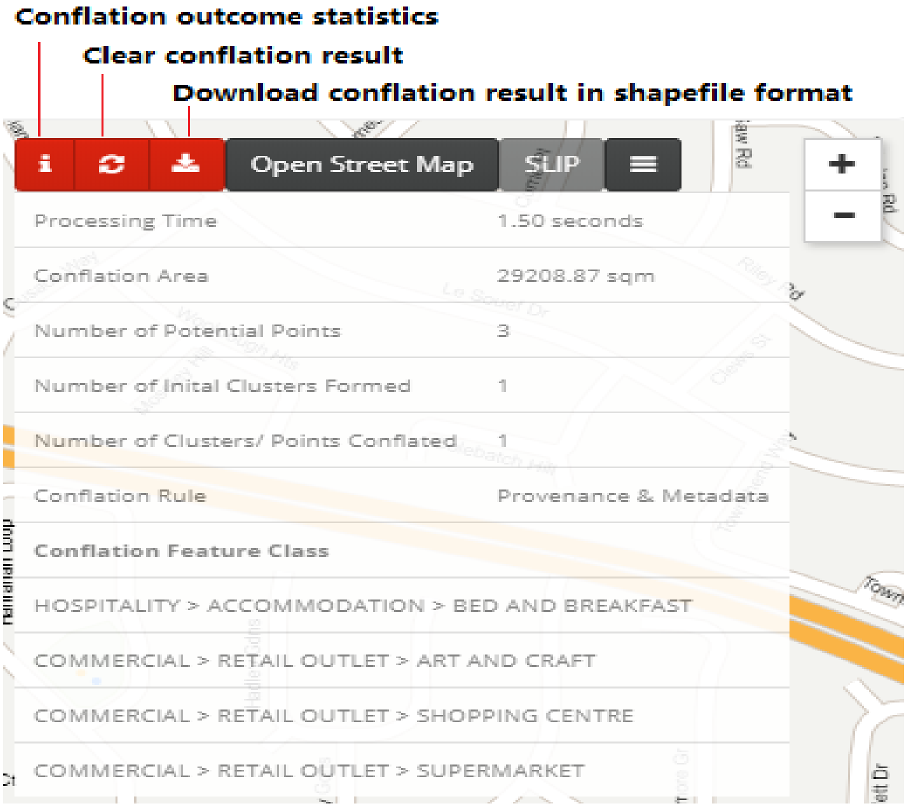

Figure 6.21 Post conflation options

6.5.3 Conclusion

The conflation of overlapping POI datasets from multiple agencies into a single, authoritative dataset to be shared by government agencies was initiative by Western Australia government agencies in 2009. Yet it failed because of the lack of human resources to do the intensive manual work including aligning source datasets, finding matches between different POIs, making appropriate decisions regarding duplicated POIs which one is the most accurate or the most fir-for-purpose. The Proof of

Concept application demonstrates the proposed AGDC system using Semantic Web technologies can successfully conflate overlapping POIs according to user's needs without human intervention.

6. 6 Summary

Incidents are often attended by more than one emergency service organisation. If each agency is using their own datasets there is a risk that information may be different leading to poor communication and coordination between first responders. A conflated single authoritative dataset is therefore desirable between agencies. This chapter showcases the conflation of three agencies' POI datasets for emergency service purposes based on the proposed AGDC system. The system implements Semantic Web technologies where ontologies and RDF data serve as the basis for the solution and SWRL rules play the core role to automate the entire conflation process. It demonstrates that using a set of rules in a sequential order, human experts' logic can be used to find the most accurate or fit-for-purpose location and conflate the remaining attributes into a single location and removing duplicate features. In this way, the conflation processes can be run automatically without human intervention.

The case study demonstrates that the proposed AGDC system can automatically conflate three POI datasets into a single one through rule chains and with the final decision based on *Provenance and Metadata Rule.* The case study results show that the AGDC system can effectively reduce duplicate points with more than half the original points are removed and greatly increase number of valid POI s by comparing the conflated dataset to each of the original data sources. The case study results also show that the AGDC system can accurately conflate multiple sources POIs with the accuracy rate of the case study is 98%.

This chapter also demonstrates the PoC portal where users can explore the original data sources of the case study and experience various settings including buffer size, interested feature classes for conflation, and the final selection rule that can affect the conflation result. The PoC portal provides a visual demonstration of the conflation processes of how three disparate WA government agencies' POI data can be automatically conflated into a single source through the AGDC system.

7 CONCLUSIONS AND FUTURE WORK

7. 1 Introduction

In Australia there are many organisations that acquire spatial data for specific areas or points of interest. They include local government authorities, State/Territory government departments and Commonwealth agencies. The vast majority of spatial data is acquired at the local government level from various suppliers. Local governments process heterogeneous sources to generate value-added products for their own customers as well as to supply data to form State or Territory level datasets. The same processes are applied to State and Territory level datasets before being supplied to national aggregators to produce nationwide datasets. This is the current status of national Spatial Data Supply Chains (SDSCs) in Australia.

Duplication of spatial data often occurs at several points along the SDSC where methods, models and workflows are applied to process or value add spatial data to meet specific agency business needs. Many processes are manual and undocumented and there is a significant reliance on human expertise and intervention. Often duplication occurs through lack of awareness that data already exists, or because no single dataset suits multiple agencies' needs.

There are many issues regarding this situation: data is captured repeatedly, redundant datasets are available, they are often inconsistent, and there is an inefficient use of resources. These lead to questions concerning which dataset is the most accurate, complete and current. To streamline the SDSC and enhance collaborative data management among agencies, a single point of truth dataset is desirable.

This research is targeting problems associated with geospatial data conflation through the development of an Automatic Geospatial Data Conflation (AGDC) system. The AGDC system is a much-needed solution towards improving the entire SDSC process. The research examines how Semantic Web Technologies, specifically RDF, OWL ontologies and SWRL rules, can be used to automate the geospatial data conflation process. This research presents a new approach to geospatial data conflation where generation of OWL ontologies based on output data models and presenting geospatial data as RDF triples serve as the basis for the solution and SWRL rules serve as the core to automate the entire geospatial data conflation processes. By using a set of SWRL rules in a sequential order, human experts' logic can be modeled to find the most accurate or best fit-for-purpose location and conflate the remaining attributes into the single location and removing duplicate features. In this way, the conflation processes can be run automatically without human intervention

This chapter reviews the research objectives and justifies how they have been met, summaries the research contributions and its significance, and discusses the research limitations as well as suggests the directions of future work.

7. 2 Research Aim and Objectives

The aim of this research was to develop an AGDC system based on Semantic Web technologies. In order to achieve this, several research objectives were defined. These objectives were achieved in this study as described below:

7.2.1 Objective 1 - Investigate and identify standard data models that can be used as conflation output data models and are fit for multiple agencies' purposes in Australia

This research investigated and identified data model suites developed by Foundation Spatial Data Framework (FSDF) efforts that are suitable for using as conflation output data models where possible and available. FSDF is a national inter-governments standardization effort aimed at providing national foundation spatial data for Australia which covers a wide range of data themes. A lot of work has been done to develop a technical data specification framework for FSDF which includes details of standardised modelling and model management. The developed FSDF standard data models are expected to be used for refining existing and producing new spatial datasets. The study details are presented in Chapter Four and an example was given as using the Point of Interest (POI) data model within the FSDF Place Name theme to be the fit-for-multipurpose output data model for this research's case study, i.e. conflating overlapping POI datasets into a single, authoritative POI dataset.

7.2.2 Objective 2 - Investigate appropriate geospatial ontology structures and creation methods for guiding the generation of ontologies that can meet conflation process needs

A review of existing Ontology-based integration Systems, especially ontology-driven geographic information systems (ODGIS) has also been carried out in Chapter Four. A hierarchical ontology structure is identified and a direct mapping between a standard theme data model and domain ontology is adopted as the ontology creation method. Application ontologies are then extended based on source datasets involved in each specific application. An example was given as generating POI domain ontologies for this research based on a POI data model and extended to accommodate multiple POI source datasets from three different Western Australia government agencies.

7.2.3 Objective 3 - Review existing tools available for transforming and managing traditional geospatial data in RDF format

Traditional geospatial data is collected, manipulated and stored in various forms depending on agencies' business needs. It brings great barriers for effectively geospatial data conflation. A comprehensive study in Chapter Three justified that geospatial data transformed into RDF format can resolve data heterogeneous barriers in the syntactic, schematic and semantic levels. Several popular geospatial RDF data converters are identified and each of their advantages and disadvantages are discussed in the same Chapter. Regarding the management of geospatial RDF data, several popular open source triple stores are provided for reference.

7.2.4 Objective 4 - Develop methodologies for creating SWRL rules that can automate the geospatial data conflation process

In order to automate the geospatial data conflation process, SWRL rules are proposed to model domain experts' conflation logic and reduce human intervention in the process. This research develops a general engineering framework for guiding the SWRL rules generation process (see Chapter Five). The framework presents a hierarchical knowledge structure from where SWRL rules can be generated. The top level is the generic geographic knowledge and common senses information. In the middle is the domain related policies, industry standards and business rules. The last level is more detailed knowledge and information that is application-specific, such as data provenance, reference datasets, application requirements, and expert experience etc.

7.2.5 Objective 5 - Evaluate the data conflation conceptual framework based on a case study.

The geospatial data conflation conceptual model is tested and evaluated with a case study. Source datasets consist of three government agencies' Point of Interest (POI) datasets to be conflated to meet emergency response needs. Chapter Six demonstrates the case study including its ontologies generation, the SWRL rule chains used in data filtering and reasoning process, the conflation data evaluation results and finally the Proof of Concept web application is presented.

The case study evaluation results demonstrate that the proposed methodology for geospatial data conflation can effectively reduce duplicate data and the conflated result is of high accuracy (98%).

7.2.6 Objective 6: Develop a Proof of Concept application as a demonstrator of the research concepts and process.

The Proof of Concept web portal developed based on the methodology offers users with experiences of automatic conflation of POI datasets. Users have options to select different categories of POI data and conflate them based on a choice of purpose. Without any further intervention, POI data conflation can be completed, and the result is available for download and for further analysis.

In summary, the achievement of each objective described above demonstrates that the research aims and objectives of developing an AGDC system based on Semantic Web technologies has been achieved overall.

7. 3 Conclusion and Recommendation for Future Research

The research problem, which has been explained in Chapter One, is that extensive duplication of spatial data exists in Australian government organisations. Conflating multiple geospatial datasets into a single authoritative dataset is challenging. It requires resolving spatial and aspatial attribute conflicts between source datasets so the best value can be retained, and duplicate features are removed. Domain experts are able to conflate data using manual comparison techniques, but the task is labour intensive when dealing with large datasets. This research emphasises the need for standardized vocabulary and query languages is necessary because the meaningful query and interchange geospatial RDF triples are relied on them. And the research demonstrates a SWRL rule-based method that models users' analytic logic and reasoning steps to automate spatial data integration. The method allows flexibility and customisation when combining large datasets. It utilises data provenance, topological relationships, business policies, workflows and rules, as well as knowledge elicited from expert users to integrate geospatial datasets in a way that can be tailored to an individual's application purpose.

This research tested the proposed AGDC system through successfully conflating three overlapping point datasets into a single one based on different user's needs. Later future work should test the framework on conflating other kinds of vector datasets with various combination, such as, among the same geometric types (polyline-to-polyline, polygon-to-polygon), or different kinds of geometric types (conflating point datasets with polyline/polygon datasets or conflating polyline datasets with polygon datasets).

Building on the research in this thesis, future research can look at the development of custom built-ins for SWRL. The SWRL rules chain demonstrated in this research are using some of the SWRL default built-ins for string matching or comparison, and different SWRL rules needed to utilise different default built-ins to cope with various situations. A single rule that compares name strings and returns a high precision rate is expected if a suitable string-matching algorithm is used to construct a custom built-in for the test case.

The extendable built-in feature of SWRL enables users to embed preferable algorithms in various comparison steps within the SWRL rule chain by using custom built-ins. Custom built-ins can return more precise results than the default built-ins. Furthermore, different conflation projects might have special needs and methods to compare different source data. If some of the process details can be developed as a custom built-in, then the SWRL rules can keep the focus on modelling key logic steps while some complex and daunting calculations and processes can be hidden in the background. In addition, spatial relationships such as touch and adjacent, and spatial functions such as buffer and intersect etc. are desirable. GeoSPARQL-Jena, which is the implementation of GeoSPARQL standard for Apache-Jena in recent development, can be further looked into if it can replace Apache-Jena to be successfully implemented in the case study and the proof of concept geospatial data conflation system. In the case of success, the original idea of encoding geospatial data based on GeoSPARQL vocabularies together with custom ontologies and incorporating GeoSPARQL query functions and analysis functions into SWRL rules for automatic reasoning can be realised. Therefore, with standard SWRL rules chaining forward to model overall decision logic and custom built-ins in single steps to cater for specific calculation or comparison requirements, the SWRL rule-based method can better serve for each individual conflation application requirements and also be able to automate all the processes at the same time.

7. 4 Final Remark

Open Linked Data and Semantic Web technologies have recently been accepted widely by the geospatial industry. The Australian government has been working closely with W3C and OGC to standardise information and technologies and promote best practice in the management and use of spatial data on the Web. Australia has established its own government linked data working group, i.e. Australian Government Linked Data Working Group (AGLDWG)[78] to develop government standards and set up Linked Data implementation techniques in response to its citizens and agencies' needs. More recently, the Australian and New Zealand Cooperative Research Centre for Spatial Information (CRCSI) published a white paper (Duckham et al., 2017) to propose moving traditional Spatial Data Infrastructures to a Next Generation Spatial Knowledge Infrastructure (SKI) which can automatically create, share, curate, deliver and use data or information, as well as knowledge creation to support decision making. Semantic Web technologies were identified as an essential element to support the SKI in connecting, integrating and analysing data.

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78 https://www.linked.data.gov.au/

To be able to appreciate the benefit of data versatility as highlighted in the SKI and embrace the advantages of Linked Data for knowledge acquisition, geospatial data conflation is an essential process for creating a single point of truth dataset from interrelated data sources, so that knowledge can be more easily derived. The novel and significant contribution of this research is the development, demonstration and evaluation of a SWRL Rule-based AGDC system that automatically matches and links corresponding entities between similar datasets, conflating these entities into a single dataset by selecting the most accurate features and removing duplicates without the need for human intervention.

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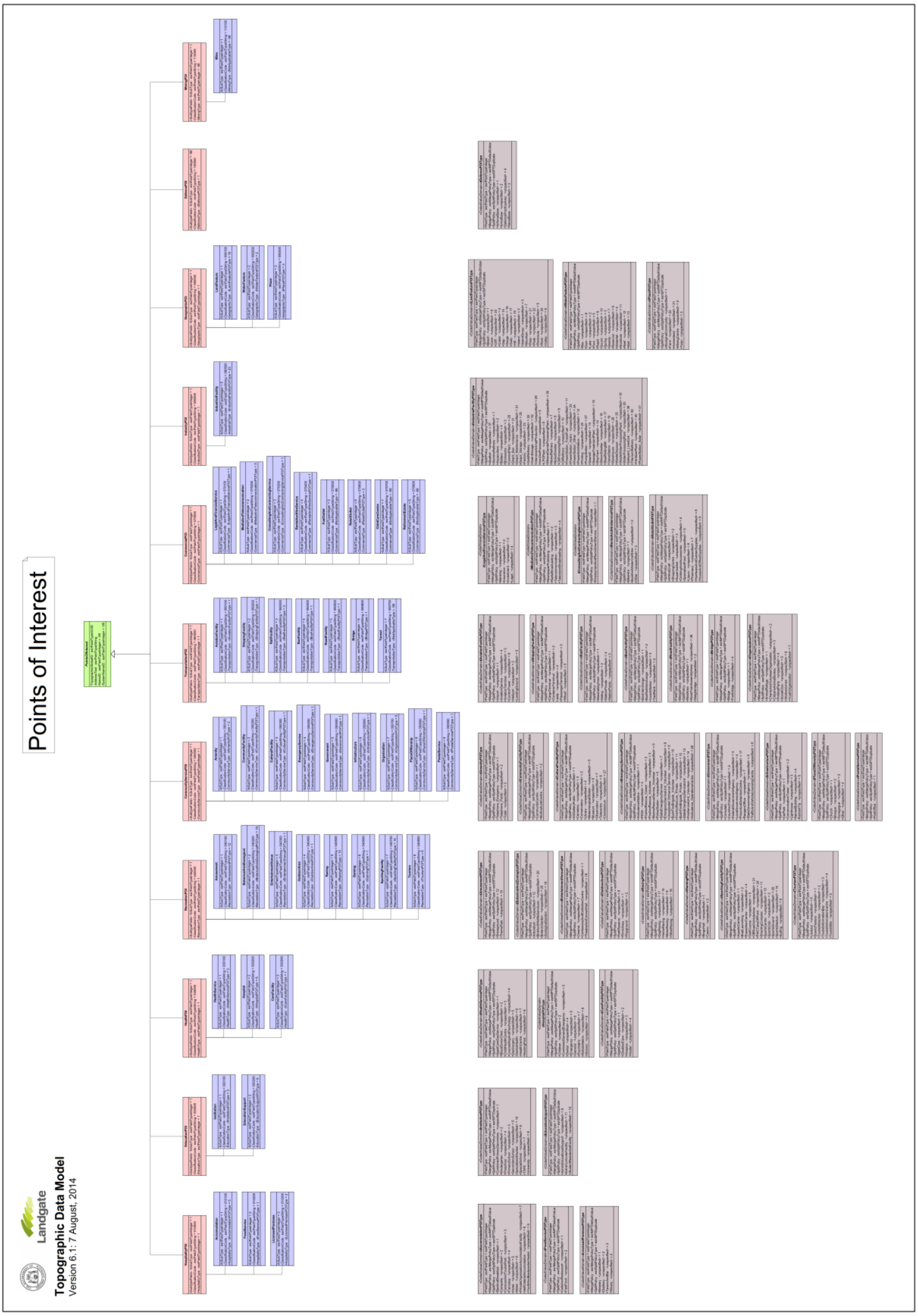
APPENDIX A - LANDGATE POINTS OF INTEREST DATA MODEL



APPENDIX B – ANALYSIS RECORDS OF CONFLATED POINTS

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
IKEA	6 SUNRAY DR, INNALOO	2	2				LG		LG	6	Y	Source from LG & DFES, both in footprint, decided by rule, result fulfill expectation
INNALOO/ CENTRO INNALOO/ WESTFIELD INNALOO/ INNALOO CITY CENTRE/ WESTFIELD INNALOO/ CENTRO INNALOO/ WESTFIELD INNALOO	46 OSWALD ST, INNALOO	8	8				LG		LG	6	Y	Source from LG(2)&DFES(5)&WAPOL(1), all in footprint, decidey by rule, but not sure how to decided between 2 LG
INNALOO/ INNALOO SHOPPING CENTRE/ INNALOO SHOPPING CENTRE	2 H MORRIS PL, INNALOO	3	1	2		F		DFES	DFES(LG address not	4	Y	Source from LG&DFES&WAPOL, autoselected by footprint (DFES inside footprint)
HUNTINGDALE/ HUNTINGDALE SHOPPING CENTRE	68-72 WARTON ROAD, HUNTINGDALE	2	2				LG		LG	5	Y	Source from LG & DFES, both in foorprint, decided by rule, result fulfill expectation
BAYSIDE SHOPPING CENTRE/ BAYSIDE	60-64 PENGUIN ROAD, SAFETY BAY	3	1	1	1	F		LG	LG	5	Y	Source from LG&DFES&WAPOL, autoselected by footprint or by rule (LG inside footprint, WAPOL in cadastre, DFES outside in the intersection)
THE INGLEWOOD SHOPPING CENTRE/ THE INGLEWOOD	9 WOOD ST	3	2	1			WAPOL		WAPOL(LG address available)	5	Y	Source from LG&DFES&WAPOL, WAPOL&DFES infootprint, LG in cadastre, decided by rule
CARRAMAR VILLAGE	7 CHERITON DR, CARRAMAR	2		2			LG		LG	3	Y	Source from LG&DFES, both in cadastre, no footprint available, chosed by rule
FOREST LAKES FORUM/ FOREST LAKES	MURDOCH ROAD, THORNLIE	2	2				LG		LG(LG address not	5	Y	source from LG&DFES, both in footprint, decided by rule
BELMONT VILLAGE	226 BELMONT AV, CLOVERDALE	2	2				LG		LG	6	Y	Source from LG&DFES, each at different footprint, decide by rule
BELMONT FORUM SHOPPING CENTRE/ BELMONT FORUM/ BELMONT FORUM	227 BELMONT AVENUE, CLOVERDALE	3	3				LG		LG	5	Y	Source from LG&DFES&WAPOL, all in a footprint, decided by rule
COOLOONGUP SHOPPING CENTRE/ COOLOONGUP	1-5 ENNIS AVENUE, COOLOONGUP	3	1	1	1	F		LG	LG	5	Y	Source from LG&DFES&WAPOL, DFES point in the intersection, only LG inside footprint, could be decided by auto/rule
MEADOWVALE SHOPPING CENTRE/ MEADOWVALE	2 MEADOWVALE AVENUE, SOUTH PERTH	3	3				LG		LG	6	Y	Source from LG&DFES&WAPOL, all in a footprint, decided by rule
LANDSDALE FORUM SHOPPING CENTRE/ LANDSDALE FORUM/ LANDSDALE FORUM/ LANDSDALE FORUM	THE BROADVIEW, LANDSDALE	4	1	3		F		LG	LG(LG address is not complete,	5	Y	2 points from LG, one inside footprint, the other in different cadastre, DFES&WAPOL in the same cadastre as the footprint locate
ALINJARRA VILLAGE SHOPPING CENTRE/ ALINJARRA VILLAGE	40 GREENPARK ROAD, ALEXANDER HEIGHTS	3	1	2		F		LG	LG	5	Y	Source from LG&DFES&WAPOL, DFES point in the intersection, only LG inside footprint, could be decided by auto/rule
BRIGHTON VILLAGE SHOPPING CENTRE/ BRIGHTON	11 KINGSBRIDGE BVD, BUTLER	3	1	1	1	F		LG	LG	5	Y	Source from LG&DFES&WAPOL, WAPOL point on the road, only LG inside footprint, could be decided by auto/rule
OCEAN KEYS SHOPPING CENTRE/ OCEAN KEYS	36 OCEAN KEYS BOULEVARD, CLARKSON	2		2			LG		LG	3	Y	Source from LG&DFES, non inside footprint, decided by rule
LAKELANDS SHOPPING CENTRE/ LAKELANDS	31 MOORHEN DRIVE, YANGEBUP	3	1	1	1	F		LG	LG	6	Y	Source from LG&DFES&WAPOL, DFES point in the intersection, only LG inside footprint, could be decided by auto/rule
RIVERTON/ RIVERTON SHOPPING CENTRE/ RIVERTON SHOPPING CENTRE	189 HIGH RD	3	2	1			WAPOL		WAPOL(both LG&WAPOL address not	5	Y	Source from LG&DFES&WAPOL, LG outside footprint; address should pick LG
THE SHOPS AT ELLENBROOK/ THE SHOPS	THE PROMENADE	4	3	1			WAPOL		WAPOL(LG address available)	4	Y	two points from DFES at the same location, LG outside footprint
PINJARRA JUNCTION/ PINJARRA JUNCTION SHOPPING CENTRE	21 GEORGE ST, PINJARRA	2	1		1	F		LG	LG	5	Y	Source from LG&DFES, DFES point in the intersection, only LG inside footprint, could be decided by auto/rule
MELVILLE PLAZA/ MELVILLE PLAZA SHOPPING CENTRE	380 H CANNING HWY, BICTON	2	1	1		F		DFES	DFES(LG address available)	4	Y	source from WAPOL&DFES, only DFES inside footprint
WILLIAM ST SHOPPING CENTRE/ WILLIAM STREET	375 WILLIAM ST, PERTH	3	1	1	1	F		LG	LG	6	Y	Source from LG&DFES&WAPOL, DFES point in the intersection, only LG inside footprint, could be decided by auto/rule
BRENTWOOD/ BRENTWOOD SHOPPING CENTRE/ BRENTWOOD SHOPPING CENTRE	66-88 CRANFORD AVENUE, BRENTWOOD	3	3				LG		LG	6	Y	Source from LG&DFES&WAPOL, all in a footprint, decided by rule
WOODLANDS VILLAGE SHOPPING CENTRE/ WOODLANDS VILLAGE	84 ROSEWOOD AV	2	1		1	F		WAPOL	WAPOL	5	Y	source from WAPOL&DFES, only WAPOL inside footprint
WELLINGTON VILLAGE SHOPPING CENTRE/ WELLINGTON VILLAGE	WELLINGTON RD	3	1	2		F		WAPOL	WAPOL(LG address available)	5	Y	source from LG&WAPOL&DFES, only WAPOL inside footprint
BELVIDERE/ BELVIDERE SHOPPING CENTRE/ BELVIDERE STREET SHOPPING CENTRE	40 BELVIDERE ST	3	1	1	1	F		WAPOL	WAPOL(LG address available)	4	Y	source from LG&WAPOL&DFES, only WAPOL inside footprint, LG address is correct, but located in another cadastre
OCEAN VILLAGE SHOPPING CENTRE/ OCEAN VILLAGE	5 KILPA CT, CITY BEACH	3	2		1		LG		LG	6	Y	source from LG&WAPOL&DFES, WAPOL on the road, the other in same footprint, decided by rule
COTTESLOE CENTRAL	460 STIRLING HWY, PEPPERMINT GROVE	3	3				LG		LG	6	Y	Source from LG&DFES&WAPOL, all in a footprint, decided by rule
NORTH LAKE SHOPPING CENTRE/ NORTH LAKE	65 NORTH LAKE ROAD, MYAREE	3	1	1	1		LG		LG	6	Y	source from LG&WAPOL&DFES, only LG inside footprint, WAPOL outside on road
KIARA/ KIARA SHOPPING CENTRE	BOTTLEBRUSH DRIVE & AUSSAT DRIVE, KIARA	2	1		1	F		LG	LG	5	Y	source from LG&DFES, only LG inside footprint, DFES outside on road intersection
SORRENTO QUAY/ SORRENTO QUAY SHOPPING CENTRE	HILLARYS BOAT HARBOUR, SOUTHSIDE DRIVE, HILLARYS	2	2				LG		LG	5	Y	source from LG&DFES, both inside footprint, decide by rule

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
SUMMERFIELD SHOPPING CENTRE/ SUMMERFIELD	GIRRAWHEEN AVENUE, GIRRAWHEEN	2	2				LG		LG(LG address not	5	Y	source from LG&DFES, both inside footprint, decide by rule
MOOLANDA VILLAGE/ MOOLANDA VILLAGE SHOPPING CENTRE	127 MOOLANDA BOULEVARD, KINGSLEY	2	2				LG		LG	5	Y	source from LG&DFES, both inside footprint, decide by rule
MULLALOO PLAZA	11 KOORANA ROAD, MULLALOO	2	2				LG		LG	5	Y	Source from LG&DFES, all in a footprint, decided by rule
MIDLAND CENTRAL	4 CLAYTON ST, MIDLAND	2	2				LG		LG	5	Y	Source from LG&DFES, all in a footprint, decided by rule
THE VALE/ THE VALE SHOPPING CENTRE	WARTON ROAD, CANNING VALE	2	1		1	F		LG	LG	5	Y	source from LG&DFES, only LG inside footprint, DFES outside on road intersection
LEEMING PARK/ LEEMING PARK SHOPPING CENTRE	1 DUNDEE STREET, LEEMING	3	1	1	1	F		LG	LG	6	Y	source from LG&DFES&WAPOL, only LG inside footprint, DFES outside on road intersection
HIGH WYCOMBE VILLAGE SHOPPING CENTRE/ HIGH WYCOMBE VILLAGE	530 KALAMUNDA RD, HIGH WYCOMBE	2	2				LG		LG	5	Y	Source from LG&DFES, all in a footprint, decided by rule
THE BENTLEY CENTRE	1140 ALBANY HIGHWAY, BENTLEY	2	2				LG		LG	6	Y	Source from LG&DFES, all in a footprint, decided by rule
BECKENHAM SHOPPING CENTRE/ BECKENHAM	202 WILLIAM STREET, BECKENHAM	3	2		1		LG		LG	5	Y	source from LG&DFES&WAPOL, WAPOL&LG inside footprint, DFES outside on road intersection, decided by rule
EDEN HILL SHOPPING CENTRE/ EDEN HILL	248 MORLEY DR E	2		1	1	C		WAPOL	WAPOL	2	Y	source from WAPOL&DFES, DFES outside on road intersection, WAPOL inside cadastre, autoselect
SHOALWATER SHOPPING CENTRE/ SHOALWATER	SAFETY BAY RD	2		2			WAPOL		WAPOL	2	N(LG available, inside footprint, didn't involve in	Source from WAPOL&DFES, both in a cadastre, decided by rule, LG point also available, didn't involve conflation
KWINANA HUB/ KWINANA HUB SHOPPING CENTRE	CORNER CHISHAM & GILMORE AVENUE, KWINANA TOWN CENTRE	2	1		1	F		LG	LG	5	Y	source from LG&DFES&WAPOL, only LG inside footprint, DFES outside on road intersection
MIRRABOOKA VILLAGE/ MIRRABOOKA VILLAGE SHOPPING CENTRE	73 HONEYWELL BOULEVARD, MIRRABOOKA	3	1	2		F		LG	LG	5	Y	source from LG&DFES&WAPOL, only LG inside footprint, DFES&WAPOL inside cadastre, auto-select
WEST ARMADALE SHOPPING CENTRE/ WEST ARMADALE	GIRRAWEEN ST	2	2				WAPOL		WAPOL	4	Y	Source from WAPOL&DFES, both in footprint, decided by rule
CRIMEA SHOPPING CENTRE/ CRIMEA	127 CRIMEA STREET, MORLEY	3	2	1			LG		LG	6	Y	source from LG&DFES&WAPOL, LG&WAPOL inside footprint, DFES inside cadastre, decided by rule
PARKWOOD SQUARE	86 VELLGROVE AV	2		1	1	C		WAPOL	WAPOL	3	Y	Source from WAPOL&DFES, WAPOL in cadastre, DFES outside on road intersection, auto-select
BIBRA LAKE SHOPPING CENTRE/ BIBRA LAKE	16 ANNOIS ROAD, BIBRA LAKE	3	2		1		LG		LG		Y	source from LG&DFES&WAPOL, LG&WAPOL inside footprint, DFES outside on road intersection, decided by rule
GARDEN CITY SHOPPING CENTRE/ GARDEN CITY	125 RISELEY ST	2	2				WAPOL		WAPOL		Y	Source from WAPOL&DFES, both in footprint, decided by rule
WOODVALE/ WOODVALE SHOPPING CENTRE/ WOODVALE SHOPPING CENTRE	153 TRAPPERS DR, WOODVALE	3	1	2			LG		LG	3	N(should auto-select DFES, but chose LG by rule? wrong; web app	source from LG&DFES&WAPOL, only DFES inside footprint, LG&WAPOL inside cadastre, should auto-select DFES, but result is in LG, wrong (might because DFES location is very close to outside footprint)
WOODVALE BOULEVARD/ WOODVALE BOULEVARD	931 WHITFORDS AV, WOODVALE	2	1	1		F		LG	LG	5	Y	source from LG&DFES&WAPOL, only LG inside footprint, DFES in cadastre, auto-select
SEACREST VILLAGE HARMAN PARK/ SEACREST/ SEACREST VILLAGE	15 HARMAN RD, SORRENTO	3		3			LG		LG	3	Y	source from LG&DFES&WAPOL, all inside cadastre, decided by rule
MINDARIE KEYS/ MINDARIE KEYS SHOPPING CENTRE/ MINDARIE KEYS SHOPPING CENTRE	28 ANCHORAGE DR, MINDARIE	3	1	2		F		LG	LG	5	Y	source from LG&DFES&WAPOL, only LG inside footprint, DFES&WAPOL in cadastre, auto-select
CLARKSON SHOPPING CENTRE/ CLARKSON	30 AINSBURY PDE, CLARKSON	4		3	1		LG		LG	3	Y	source from LG&DFES&WAPOL, 2 WAPOL & 1 Lg in cadastre, DFES outside on the road intersection, decided by rule
SHELLEY HUB/ SHELLEY HUB SHOPPING CENTRE	15-19 TRIBUTE STREET WEST, SHELLEY	3	2	1			LG		LG	6	Y	source from LG&DFES&WAPOL, WAPOL&LG inside footprint, DFES in cadastre, decided by rule
BULLSBROOK/ BULLSBROOK SHOPPING CENTRE/ BULLSBROOK SHOPPING CENTRE	2529 GREAT NORTHERN HIGHWAY, BULLSBROOK	3		3			LG		LG	3	Y	source from LG&DFES&WAPOL, no footprint available, all inside cadastre, decided by rule
ROLEYSTONE SHOPPING CENTRE/ ROLEYSTONE	15 WYGONDA ROAD, ROLEYSTONE	3	2	1			LG		LG	5	Y	source from LG&DFES&WAPOL, WAPOL&LG inside footprint, DFES outside on road intersection, decided by rule
ROSTRATA/ ROSTRATA SHOPPING CENTRE/ ROSTRATA SHOPPING CENTRE	40-48 ROSTRATA AVENUE, WILLETTON	3	1	2		F		LG	LG	6	Y	source from LG&DFES&WAPOL, only LG inside footprint, DFES&WAPOL in cadastre, auto-select
CARCOOLA SHOPPING CENTRE	CARCOOLA AV	2	1	1		F		WAPOL	WAPOL	4	Y(LG address	source from LG&WAPOL, WAPOL inside footprint, LG in cadastre, auto-select
PORT KENNEDY SHOPPING CENTRE WARNBRO SOUND AV/ PORT KENNEDY SHOPPING CENTRE WARNBRO SOUND	371 WARNBRO SOUND AV, PORT KENNEDY	2					LG		LG	5	Y	Source from WAPOL&LG, both in footprint, decided by rule
WEMBLEY SHOPPING CENTRE GRANTHAM ST	, WEMBLEY	2			2		LG		LG	3	Y	Source from WAPOL&LG, both outside on road, decided by rule
WEMBLEY SHOPPING CENTRE NANSON ST	290 CAMBRIDGE ST	2	1	1		F		WAPOL	WAPOL(LG address available)	5	Y	Source from WAPOL&LG, WAPOL inside footprint, LG in cadastre, auto-select
WEMBLEY SHOPPING CENTRE CAMBRIDGE ST/ WEMBLEY SHOPPING CENTRE	334 CAMBRIDGE ST, WEMBLEY	2	2				LG		LG	6	Y	Source from WAPOL&LG, both in footprint (2 different), decided by rule
RAILWAY PARADE	3 RAILWAY PDE, GLEN FORREST	2		2			LG		LG	3	Y	Source from WAPOL&LG, both in cadastre, decided by rule
SOUTHERN RIVER SHOPPING CENTRE GOSNELLS	GEORGE ST	2	1	1		F		WAPOL	WAPOL(LG address available)	4	Y	Source from WAPOL&LG, WAPOL in footprint, LG in cadastre, auto-select
CORONATION SHOPPING CENTRE	156 RAILWAY PDE, QUEENS PARK	2	1	1		F		LG	LG	5	Y	Source from WAPOL&LG, LG in footprint, WAPOL in cadastre, auto-select
FURNISSDALE WEEKEND MARKETS	566 PINJARRA RD	3	1	2		F		WAPOL	WAPOL(LG address available)	4	Y	Source from WAPOL&LG, WAPOL in footprint, 2 LG in cadastre, auto-select
LEEMING SHOPPING FORUM	51 FARRINGTON ROAD, LEEMING	2		2			LG		LG	4	Y	Source from WAPOL&LG, both in cadastre, decided by rule

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
KINROSS CENTRAL/ KINROSS CENTRAL SHOPPING CENTRE	3 SELKIRK DR, KINROSS	3	1	1	1	F		LG	LG	5	Y	source from LG&DFES&WAPOL, LG inside footprint, WAPOL in cadastre, DFES outside on road intersection, auto-select
TWO ROCKS VILLAGE SHOPPING CENTRE/ TWO ROCKS	ENTERPRISE AV	2		1	1	C	WAPOL	WAPOL	WAPOL	2	Y	source from DFES&WAPOL, WAPOL in cadastre, DFES outside on road, auto-select
ATLANTIS VILLAGE	8 ENTERPRISE AV, TWO ROCKS	2	1		1	F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES on road, auto-select
OLD COAST PLAZA		3		3			LG		N/A	3	Y?(2 LG points, 1 address available, empty because selected the one without address)	2 points from LG, 1 from DFES, all in cadastre, decide by rule, but not sure how to decided between 2 LG
THE SANDS SHOPPING CENTRE/ THE SANDS	175-179 MANDURAH TERRACE, MANDURAH	2	1		1	F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES on road, auto-select
CHIDLOWS WELL VILLAGE/ CHIDLOWS WELL VILLAGE SHOPPING CENTRE	THOMAS ST	2		2			WAPOL		WAPOL(DFES address	2	Y	source from DFES&WAPOL, all in cadastre(LG inside cadastre too, no footprint available), decided by rule
FOOTHILLS/ FOOTHILLS SHOPPING CENTRE	CORNER ALBANY HIGHWAY & DOROTHY STREET, GOSNELLS	2	1		1	F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES on road, auto-select
GOSNELLS RAILWAY MARKETS/ RAILWAY MARKETS/ RAILWAY MARKETS	1 FREMANTLE RD, GOSNELLS	3	1	2		F		LG	LG	3	Y	source from LG&DFES&WAPOL, LG inside footprint, WAPOL&DFES in cadastre, auto-select
BARBERRY SQUARE/ BARBERRY SQUARE SHOPPING CENTRE	12 BARBER STREET, KALAMUNDA	3	2	1			LG		LG	5	Y	source from LG&DFES&WAPOL, LG inside footprint, WAPOL&DFES in cadastre,decided by rule
CENTRO KALAMUNDA/ KALAMUNDA	39 RAILWAY ROAD, KALAMUNDA	4	4				LG		LG	5	Y	source from LG&DFES(2 points)&WAPOL, all inside footprint, decided by rule
KALAMUNDA CENTRAL	39 H RAILWAY RD, KALAMUNDA	2	1	1		F		DFES	DFES	3	Y(these six points should be conflated, separated due to	Source from DFES&WAPOL, DFES in footprint, WAPOL in cadastre, auto-select
GLEN FORREST/ GLEN FORREST SHOPPING CENTRE	1320 GREAT EASTERN HWY, GLEN FORREST	3	2	1			LG		LG	5	Y	source from LG&DFES&WAPOL, LG&DFES inside footprint, WAPOL in cadastre, decided by rule
CLOISTERS SQUARE	200 ST GEORGES TCE, PERTH	2	2				LG		LG	6	Y	source from LG&WAPOL, both inside footprint (2 different), decided by rule
ARCADE 800	800 HAY ST	2	2				WAPOL		WAPOL	5	Y	source from DFES&WAPOL, both inside footprint, decided by rule
TRINITY ARCADE	671 HAY ST	2	2				WAPOL		WAPOL	5	Y	source from DFES&WAPOL, both inside footprint, decided by rule
CENTRO DAVID JONES PERTH/ DAVID JONES	646 H HAY ST, PERTH	2	2				DFES		DFES	4	Y	2 points from DFES (same location), both in footprint
LONDON COURT	HAY ST, PERTH	3	1	2		F		DFES	DFES	4	Y(LG address correct, available)	source from LG&DFES&WAPOL, DFES inside footprint, WAPOL&LG in cadastre, auto-select
PLAZA ARCADE/ PLAZA ARCADE PERTH	650 H HAY ST, PERTH	2	1	1		F		DFES	DFES	4	Y(WAPOL	source from DFES&WAPOL, DFES inside footprint, WAPOL in cadastre, auto-select
PICCADILLY ARCADE	HAY ST AND MURRAY ST	2	2				WAPOL		WAPOL	5	Y	source from WAPOL&DFES, both in footprint, decided by rule
FORREST CHASE	419 WELLINGTON ST, PERTH	2	2				LG		LG	6	Y	source from LG&DFES, both in footprint, decided by rule
THE BAY CENTRE	2 HOKIN ST, WAIKIKI	3		2	1		LG		LG	3	Y	source from LG&DFES&WAPOL, DFES out on road, WAPOL&LG in cadastre, decided by rule
KALLAROO/ KALLAROO SHOPPING CENTRE/ KALLAROO SHOPPING CENTRE	3-5 ADALIA STREET, KALLAROO	3	2	1			LG		LG	5	Y	source from LG&DFES&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
THE BOULEVARD SHOPPING CENTRE/ THE BOULEVARD/ BOULEVARD SHOPPING CENTRE	316 THE BOULEVARD, CITY BEACH	3	3				LG		LG	6	Y	source from LG&DFES&WAPOL, all in footprint, decided by rule
STIRLING CENTRAL	478 WANNEROO RD, WESTMINSTER	3	3				LG		LG	5	Y	source from LG&DFES&WAPOL, all in footprint, decided by rule
FIELDGATE SQUARE SHOPPING CENTRE/ FIELDGATE SQUARE/ FIELDGATE SQUARE	25 CULLOTON CRESCENT, BALGA	3	2	1			LG		LG	5	Y	source from LG&DFES&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
MALAGA MARKETS	BEACH ROAD, MALAGA	3	3				LG		LG	5	Y	source from LG&DFES&WAPOL, all in footprint, decided by rule
ARMADALE SHOPPING CITY	206 JULL STREET, ARMADALE	2	2				LG		LG	5	Y	source from LG&DFES, both in footprint, decided by rule
ARMADALE CENTRAL/ ARMADALE CENTRAL SHOPPING CENTRE	10 ORCHARD AV, ARMADALE	2	2				LG		LG	5	Y	source from LG&DFES, both in footprint (2 different), decided by rule
ARMADALE PLAZA	352 H STREICH AV, ARMADALE	2	1	1		F		DFES	DFES	3	Y(DFES address	source from WAPOL&DFES, DFES in footprint, WAPOL in cadastre, auto-select
BEECHBORO CENTRAL/ BEECHBORO CENTRAL SHOPPING CENTRE	412 BEECHBORO ROAD, MORLEY	3	1	1	1	F		LG	LG	6	Y	source from LG&DFES&WAPOL, LG in footprint, WAPOL in cadastre, DFES outside on road, auto-select
COTTESLOE MEWS/ COTTESLOE MEWS SHOPPING CENTRE	36 ERIC STREET, COTTESLOE	3	3				LG		LG	6	Y	source from LG&DFES&WAPOL, all in footprint, decided by rule
MEADOW SPRINGS/ MEADOW SPRINGS SHOPPING CENTRE	MEADOW SPRINGS DRIVE, MEADOW SPRINGS	2		2			LG		LG	3	Y	source from LG&DFES, all in cadastre, decided by rule
LOVE ST CLOVERDALE SHOPPING CENTRE/ LOVE STREET	11 LOVE ST	2	2				WAPOL		WAPOL	3	Y	Source from DFES&WAPOL, both in footprint, decided by rule
DALKEITH VILLAGE/ DALKEITH VILLAGE SHOPPING CENTRE	79-101 WARATAH AVENUE, DALKEITH	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
BROADWAY FAIR/ BROADWAY FAIR SHOPPING CENTRE	88 BROADWAY	3	2	1			WAPOL		WAPOL	5	Y(LG address available, DFES	source from LG&DFES&WAPOL, WAPOL&DFES in footprint, LG in cadastre, decided by rule
VILLAGE GREEN SHOPPING CENTRE KARAWARA/ VILLAGE GREEN	MANNING RD AND KENT ST	2	1		1	F		WAPOL	WAPOL	5	Y	Source from DFES&WAPOL, WAPOL in footprint, DFES out on road, auto-select
WATERFORD PLAZA	CORNER MANNING ROAD & KENT STREET, KARAWARA	2	1	1		F		LG	LG	6	Y	Source from DFES&LG, LG in footprint, DFES out on road auto-select
CENTRO WARNBRO	206 H WARNBRO SOUND AV, WARNBRO	2	1	1		F		DFES	DFES	3	Y	Source from DFES&WAPOL, DFES in footprint, WAPOL in cadastre, auto-select
WARNBRO FAIR/ WARNBRO	206 WARNBRO SOUND AV, WARNBRO	3	3				LG		LG	5	Y(these two conflated points should be conflated but excluded cause name different, addresses are same, maybe	2 points from DFES (same location)&LG, all in footprint, decided by rule
KOONDOOLA PLAZA	28-38 KOONDOOLA AVENUE, KOONDOOLA	3	1	2		F		LG	LG	5	Y	source from LG&DFES&WAPOL, WAPOL&DFES in cadastre, LG in footprint, auto-select
KINGSLEY VILLAGE SHOPPING CENTRE/ KINGSLEY VILLAGE	86 KINGSLEY DR	2		2			WAPOL		WAPOL	2	Y	Source from DFES&WAPOL, both in cadastre, decided by rule
HEATHRIDGE SHOPPING CENTRE/ HEATHRIDGE	89 CARIDEAN ST, HEATHRIDGE	3	1	2		F		LG	LG	5	Y	source from LG&DFES&WAPOL, WAPOL&DFES in cadastre, LG in footprint, auto-select

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
BELDON SHOPPING CENTRE/ BELDON	9 GUNTER GROVE, BELDON	3	2	1			LG		LG	5	Y	source from LG&DFES&WAPOL, WAPOL in cadastre, LG&DFES in footprint, decided by rule
MIDLAND GATE SHOPPING CENTRE/ MIDLAND GATE	274 GREAT EASTERN HIGHWAY, MIDLAND	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
STOCKLAND BALDIVIS/ BALDIVIS	SAFETY BAY RD, BALDIVIS	2	2				DFES		DFES	1		single source from DFES(2 points), same location, both in footprint
STRATTON PARK SHOPPING CENTRE/ STRATTON PARK/ STRATTON PARK	3 JECKS PLACE, STRATTON	3	2	1			LG		LG	5	Y	Source from WAPOL&DFES&LG, LG&DFES in footprint, WAPOL in cadastre,decided by rule
CURRAMBINE MARKET PLACE/ CURRAMBINE MARKETPLACE	1244 MARMION AVENUE, CURRAMBINE	3	2	1			LG		LG	5	Y	Source from WAPOL&DFES&LG, LG&WAPOL in footprint, DFES out on road intersection,decided by rule
STARGATE KELMSCOTT	2784 ALBANY HIGHWAY, KELMSCOTT	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
KELMSCOTT VILLAGE SHOPPING CENTRE/ KELMSCOTT VILLAGE/ KELMSCOTT/ KELMSCOTT VILLAGE	2865 H ALBANY HWY, KELMSCOTT	4	2	2			DFES		DFES	3	Y(?not sure how to decide between two DFES)	2 points from DFES, in different footprint, WAPOL&LG in cadastre, decided by ?
GLENGARRY SHOPPING CENTRE/ GLENGARRY	CORNER GLENGARRY DRIVE & AMISDALE ROAD, DUNCRAIG	3	2	1			LG		LG	5	Y	Source from WAPOL&DFES&LG, LG&DFES in footprint, WAPOL in cadastre,decided by rule
MAIDA VALE/ MAIDA VALE SHOPPING CENTRE/ MAIDA VALE SHOPPING CENTRE	431 KALAMUNDA ROAD, HIGH WYCOMBE	3	3				LG		LG	5	Y	Source from WAPOL&DFES&LG, all in footprint, decided by rule
ERSKINE CENTRAL SHOPPING CENTRE/ ERSKINE CENTRAL	36 WATTLEGLEN AVENUE, ERSKINE	3	3				LG		LG	5	Y	Source from WAPOL&DFES&LG, all in footprint, decided by rule
THE PLAZA SHOPPING CENTRE/ THE PLAZA SHOPS	CORNER TUCKEY STREET & MANDURAH TERRACE, MANDURAH	2		1	1	C		LG	LG	3	Y	Source from DFES&LG, LG in cadastre, DFES out on road intersection, auto-select
SCOTTS PLAZA		3	2	1			LG		N/A	5	Y(another LG point exist, address available)	2 points from LG, both inside footprint, WAPOL in cadastre, not sure how to decided between 2 LG points
MANDURAH CENTRAL/ MANDURAH CENTRE SHOPPING CENTRE/ MANDURAH CENTRAL SHOPPING CENTRE	CORNER TUCKEY STREET & MANDURAH TERRACE, MANDURAH	3	3				LG		LG	5	Y	Source from WAPOL&DFES&LG, all in footprint, decided by rule
SUTTON SQUARE/ SUTTON SQUARE SHOPPING CENTRE	16 TUCKEY STREET, MANDURAH	3	3				LG		LG	5	Y	Source from WAPOL&DFES&LG, all in footprint, decided by rule
NORTH BEACH SHOPPING CENTRE/ NORTH BEACH	5 NORTH BEACH ROAD, NORTH BEACH	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
MADDINGTON CENTRAL	2041 ALBANY HWY	3	2	1			WAPOL		WAPOL	4	Y(LG address	Source from WAPOL&DFES&LG, WAPOL&DFES in footprint, LG in cadastre, decided by rule
ASHBURTON VILLAGE SHOPPING CENTRE/ ASHBURTON VILLAGE	64 STENNETT STREET, GOSNELLS	3	2		1		LG		LG	5	Y	Source from WAPOL&DFES&LG, WAPOL&LG in footprint, LG out on road intersection, decided by rule
KOOYONG ROAD SHOPPING CENTRE/ KOOYONG	116 H KOOYONG RD, RIVERVALE	3	1	2		F		DFES	DFES(LG address available)	4	Y	Source from WAPOL&DFES&LG, DFES in footprint, LG &WAPOL in cadastre, auto-select
STARGATE WAIKIKI/ WAIKIKI	78 H CHARTHOUSE RD, WAIKIKI	2	2				DFES		DFES	3	Y	both from DFES, same location
CHARTHOUSE SHOPPING CENTRE	78 CHARTHOUSE RD, WAIKIKI	2	2				LG		LG	5	Y(these two conflated points are the same one, but complicated to	Source from WAPOL&LG, both in footprint, decided by rule
HILLARYS/ HILLARYS SHOPPING CENTRE/ HILLARYS SHOPPING CENTRE	CORNER FLINDERS AVENUE & WATERFORD DRIVE, HILLARYS	3	3				LG		LG	5	Y(WAPOL&DFES address are the same, better)	Source from WAPOL&DFES&LG, all in footprint, decided by rule
ORELIA/ ORELIA SHOPPING CENTRE/ ORELIA SHOPPING CENTRE	62 ORELIA AVENUE, ORELIA	3	2	1			LG		LG	5	Y	Source from WAPOL&DFES&LG, DFES&LG in footprint, WAPOL in cadastre, decided by rule
FLINDERS SQUARE	FLINDERS ST	2	2				WAPOL		WAPOL	5	Y(These two conflated points are the same point, should be	Source from WAPOL&DFES, both inside footprint, decided by rule
CENTRO FLINDERS/ CENTRO FLINDERS SQUARE	FLINDERS STREET, YOKINE	3	3				LG		LG	6	Y	Source from WAPOL&DFES&LG, all in footprint, decided by rule
MIRRABOOKA SQUARE SHOPPING CENTRE/ MIRRABOOKA SQUARE/ MIRRABOOKA SQUARE	43 YIRRIGAN DRIVE, MIRRABOOKA	3	3				LG		LG	6	Y	Source from WAPOL&DFES&LG, all in footprint, decided by rule
SCARBOROUGH SHOPPING CENTRE	241 WEST COAST HWY, SCARBOROUGH	2	1	1			LG		LG	6	Y	Source from WAPOL&LG, both in footprint, decided by rule
SCARBOROUGH FAIR MARKETS/ SCARBOROUGH	10 SCARBOROUGH BEACH ROAD,	3	3				LG		LG	6	Y	2 from DFES, 1 from LG, all in footprint, decided by rule
HAMPTON PARK SHOPPING CENTRE/ HAMPTON PARK	13 PAINE ROAD, MORLEY	3	2	1			LG		LG	6	Y	Source from WAPOL&DFES&LG, DFES&LG in footprint, WAPOL in cadastre, decided by rule
FREMANTLE MARKETS	74 SOUTH TERRACE, FREMANTLE	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
WOOLSTORES/ WOOLSTORES SHOPPING CENTRE	28 CANTONMENT STREET, FREMANTLE	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
LAKES/ LAKES SHOPPING CENTRE	CORNER NORTH LAKE ROAD & OMEO STREET, SOUTH LAKE	2	1		1	F		LG	LG	6	Y	Source from DFES&LG, LG in footprint, DFES out on road, auto-select
HOMETOWN BIBRA LAKE/ HOMETOWN	25 H PORT KEMBLA DR, BIBRA LAKE	2	2				DFES		DFES	4	Y	both from DFES, same location
STOCK ROAD MARKETS	44 PORT KEMBLA DR, BIBRA LAKE	3	2		1		LG		LG	6	Y	Source from WAPOL&DFES&LG, WAPOL&LG in footprint, DFES in cadastre, decided by rule
SUBIACO PAVILION MARKETS	10 ROKEBY RD, SUBIACO	2	1		1	F		LG	LG	6	Y	Source from DFES&LG, LG in footprint, DFES out on road, auto-select
CROSSWAYS ROKEBYS/ CROSSWAYS	184 ROKEBY RD	2	1		1	F		WAPOL	WAPOL	5	Y	Source from DFES&WAPOL, WAPOL in footprint, DFES out on road, auto-select
HOMEBASE/ HOME BASE SHOPPING CENTRE/ HOME BASE EXPO	CORNER HARBORNE STREET & SALVADO ROAD, WEMBLEY	3	2	1			LG		LG	6	Y	Source from WAPOL&DFES&LG, DFES&LG in footprint, WAPOL in cadastre, decided by rule
SUBIACO SQUARE SHOPPING CTR/ SUBIACO SQUARE/ SUBI SQUARE	29 STATION STREET, SUBIACO	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
STATION STREET MARKET/ STATION STREET MARKETS/ SUBIACO SQUARE STATION STREET MARKETS	STATION ST	3	1	2		F		WAPOL	WAPOL	5	Y(LG&DFES address available,	Source from DFES&LG&WAPOL, WAPOL in footprint, LG&DFES in cadastre, auto-select
SUBIACO VILLAGE SHOPPING CENTRE/ SUBIACO VILLAGE	HAY ST AND RAILWAY RD	3	1	2		F		WAPOL	WAPOL	5	Y(LG&DFES address available,	Source from DFES&LG&WAPOL, WAPOL in footprint, LG&DFES in cadastre, auto-select
BEACONSFIELD PLAZA/ BEACONSFIELD PLAZA SHOPPING CENTRE	147 MICHAEL STREET, BEACONSFIELD	2	1	1		F		LG	LG	6	Y	Source from DFES&LG, LG in footprint, DFES in cadastre, auto-select

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
WANNEROO MARKETS/ WANNEROO MARKET	CORNER PRINDIVILLE DRIVE & ISMAIL STREET, WANGARA	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
CONNOLLY SHOPPING CENTRE/ CONNOLLY	1 GLENELG PLACE, CONNOLLY	3		3			LG		LG	3	Y	Source from DFES&LG&WAPOL, all in cadastre, decided by rule
MINDARIE COMMERCIAL CENTRE	360 ANCHORAGE DR, MINDARIE	3		2	1		LG		LG	3	Y	Source from DFES&LG&WAPOL, LG&WAPOL in cadastre, DFES out on road intersection, decided by rule
ROSSMOYNE/ ROSSMOYNE SHOPPING CENTRE	55 CENTRAL ROAD, ROSSMOYNE	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
WAIKIKI VILLAGE/ WAIKIKI VILLAGE SHOPPING CENTRE	READ STREET, WAIKIKI	2	1		1	F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES out on road, auto-select
WARATAH/ WARATAH SHOPPING CENTRE/ WARATAH SHOPPING CENTRE	98 WARATAH BVD, CANNING VALE	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
THE MEZZ SHOPPING CENTRE/ THE MEZZ	148 SCARBOROUGH BEACH ROAD, MT	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
STARGATE ATWELL/ ATWELL	129 LYDON BOULEVARD, ATWELL	4	4				LG		LG	6	Y	Source from DFES (2points, same location)&LG&WAPOL, all in footprint, decided by rule
DUNCRAIG SHOPPING CENTRE/ DUNCRAIG	50 MARRI ROAD, DUNCRAIG	3	1	2		F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL&DFES in cadastre, auto-select
SOUTH FREMANTLE SHOPPING CENTRE/ SOUTH FREMANTLE	195 HAMPTON ROAD, SOUTH FREMANTLE	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
DIANELLA/ CENTRO DIANELLA/ CENTRO DIANELLA/ CENTRO DIANELLA	CORNER ALEXANDER DRIVE & GRAND PROMENADE, DIANELLA	4	2		2		LG		LG	6	Y	Source from DFES(2 points, same location)&LG&WAPOL, LG&WAPOL in footprint, DFES out on road, decided by rule
STARGATE LEDA/ LEDA	8 FEILMAN DRIVE, LEDA	4	2		2		LG		LG	5	Y	Source from DFES(2 points, same location)&LG&WAPOL, LG&WAPOL in footprint, DFES out on road, decided by rule
CENTRO WARWICK/ WARWICK	CORNER BEACH & ERINDALE ROAD, WARWICK	4	4				LG		LG	5	Y	Source from DFES(2 points, same location)&LG&WAPOL, all in footprint, decided by rule
STARGATE SPEARWOOD/ SPEARWOOD	432 ROCKINGHAM ROAD, SPEARWOOD	3		3			LG		LG	4	Y	Source from DFES(2 points, same location)&LG, all in cadastre, decided by rule
GREENFIELDS SHOPPING CENTRE/ GREENFIELDS		2		2			LG		LG	3	Y(2 LG points very close, the other one has address but no name, didn't involve in	Source from DFES&LG, both in cadastre, decided by rule
KALAMUNDA GLADES SHOPPING CENTRE/ KALAMUNDA GLADES	123 CANNING ROAD, KALAMUNDA	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
SPENCER VILLAGE/ SPENCER VILLAGE SHOPPING CENTRE	SPENCER ROAD, THORNLIE	2	1	1		F		LG	LG	5	Y(DFES's location and address are better in reality)	Source from DFES&LG, LG in footprint, DFES in cadastre, auto-select
SOUTHERN RIVER/ SOUTHERN RIVER SHOWROOMS	714 L RANFORD RD, SOUTHERN RIVER	2	2				DFES		DFES	3	Y?(2 points in the same location, but two address are different, the one selected better, but not sure how	2 points from DFES(same location), both inside footprint, not sure how to decided between these two
LESMURDIE SHOPPING CENTRE/ LESMURDIE	241-243 LESMURDIE ROAD, LESMURDIE	3	1	2		F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL&DFES in cadastre, auto-select
LYNN STREET SHOPPING CENTRE/ LYNN STREET	117 LYNN STREET, TRIGG	3	2	1			LG		LG	6	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
GOLDEN BAY/ GOLDEN BAY SHOPPING VILLAGE	19-21 DAMPIER DRIVE, GOLDEN BAY	2	1	1		F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES in cadastre, auto-select
MOSMAN PARK/ MOSMAN PARK SHOPPING CENTRE/ MOSMAN PARK HARVEY STREET SHOPPING CENTRE	50 HARVEY STREET, MOSMAN PARK	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
PARRY VILLAGE SHOPPING CENTRE	118 PARRY AVENUE, BULL CREEK	2		2			LG		LG	4	Y	Source from LG&WAPOL, both in cadastre, decided by rule
WESTMINSTER SHOPPING CENTRE/ WESTMINSTER	108 PRINCESS RD	2	1		1	F		WAPOL	WAPOL	4	Y	Source from DFES&WAPOL, WAPOL in footprint, DFES out on road, auto-select
STIRLING VILLAGE/ STIRLING VILLAGE SHOPPING CENTRE	4-8 SANDERLING STREET, STIRLING	2	1		1	F		LG	LG	6	Y	Source from DFES&LG, LG in footprint, DFES out on road, auto-select
WANNEROO CENTRAL SHOPPING CENTRE/ WANNEROO CENTRAL/ WANNEROO CENTRAL	950 WANNEROO RD	3	2	1			WAPOL		WAPOL	4	Y	Source from DFES&LG&WAPOL, WAPOL&DFES in footprint, LG in cadastre, decided by rule
E SHED MARKETS	1 CLIFF ST, FREMANTLE	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
THE PARK CENTRE	789 ALBANY HIGHWAY, EAST VICTORIA PARK	2	2	1			LG		LG	6	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
FLOREAT FORUM	HOWTREE PLACE, FLOREAT	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
HILTON/ HILTON ARCADE SHOPPING CENTRE/ HILTON SHOPPING CENTRE/ HILTON SHOPPING CENTRE/ HILTON ARCADE/ HILTON SQUARE	279 SOUTH ST	6	4	1	1		WAPOL		WAPOL	5	N	Source from LG(1)&WAPOL(2)&DFES(3), WAPOL(2)&DFES(2) in footprint, LG(1)&DFES(1) in cadastre, decided by rule, but points should not be conflated due to name different
EAST FREMANTLE SHOPPING CENTRE/ EAST FREMANTLE	147-155 CANNING HIGHWAY, EAST	3	2	1			LG		LG	6	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
ALEXANDER HEIGHTS/ ALEXANDER HEIGHTS SHOPPING CENTRE/ ALEXANDER HEIGHTS SHOPPING CENTRE	CORNER MIRRABOOKA AVENUE & GRIFFON WAY, ALEXANDER HEIGHTS	3	2		1		LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&WAPOL in footprint, DFES out on road, decided by rule
KINGSWAY CITY	182 WANNEROO RD, MADELEY	2	1	1		F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES in cadastre, auto-select
CENTRO VICTORIA PARK/ VICTORIA PARK	366 ALBANY HWY	4	1	1	2	F		WAPOL	WAPOL	5	Y	Source from DFES(2 points, same location)&LG&WAPOL, WAPOL in footprint, LG in cadastre, DFES out on road, auto-select
CENTREPOINT SHOPPING CENTRE/ CENTREPOINT	307 GREAT EASTERN HWY, MIDLAND	3	1	2		F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL&DFES in cadastre, auto-select
ROCKINGHAM CITY SHOPPING CENTRE/ ROCKINGHAM CITY	1 COUNCIL AV	2	2				WAPOL		WAPOL	4	Y	Source from DFES&WAPOL, both in footprint, decided by rule
CANDLEWOOD VILLAGE/ CANDLEWOOD VILLAGE SHOPPING CENTRE/ CANDLEWOOD VILLAGE SHOPPING CENTRE	45-49 CANDLEWOOD BOULEVARD, JOONDALUP	3	1	1		F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL&DFES in cadastre, auto-select
SOUTHLANDS BOULEVARDE	PINETREE GULLY ROAD, WILLETTON	3	2	1			LG		LG	6	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
LILBURNE SHOPPING CENTRE/ LILBURNE	75 HILARION ROAD, DUNCRAIG	3	3				LG		LG	5	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
NEWBURN ROAD SHOPPING CENTRE/ NEWBURN	33-55 NEWBURN ROAD, HIGH WYCOMBE	2	2				LG	DFES	LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
MANDURAH FORUM	1 H ARNOLD ST, MANDURAH	2	1	1		F		DFES	DFES	3	Y(same point, but bit complicate to be conflated)	Source from DFES&WAPOL, DFES in footprint, WAPOL in cadastre, auto-select
CENTRO MANDURAH/ CENTRO MANDURAH FORUM	330 PINJARRA ROAD, MANDURAH	3	2	1			LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
KARRINYUP SHOPPING CENTRE/ KARRINYUP	200 KARRINYUP ROAD, KARRINYUP	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
MADDINGTON SQUARE	72 ATTFIELD ST, MADDINGTON	2	1	1		F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES in cadastre, auto-select
CENTRO MADDINGTON/ MADDINGTON	CORNER BURSLEM DRIVE & ATTFIELD STREET, MADDINGTON	3	1		1	F		LG	LG	5	Y	Source from DFES(2 points, same location)&LG, LG in footprint, DFES out on road, auto-select
HARBOUR TOWN/ HARBOUR TOWN SHOPPING CENTRE	830 WELLINGTON STREET, WEST PERTH	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
CITY WEST SHOPPING CENTRE/ CITY WEST/ CITY WEST	SUTHERLAND STREET, WEST PERTH	3	2	1			LG		LG	6	Y(DFES address	Source from DFES&LG&WAPOL, LG&WAPOL in footprint, DFES in cadastre, decided by rule
PADBURY SHOPPING CENTRE/ PADBURY	75 WARBURTON AVENUE, PADBURY	3	1	2		F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint, DFES&WAPOL in cadastre, auto-select
WESTFIELD WHITFORD CITY/ WHITFORD CITY	CORNER MARMION & WHITFORDS AVENUE, HILLARYS	4	4				LG		LG	5	Y	Source from DFES(2 points, same location)&LG&WAPOL, all in footprint, decided by rule
SOMERVILLE/ SOMERVILLE SHOPPING CENTRE/ SOMERVILLE SHOPPING CENTRE	134 LE SOUEF DRIVE, KARDINYA	3	1	1	1	F		LG	LG	6	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL in cadastre, DFES out on road, auto-select
THE DOWNS SHOPPING CENTRE/ THE DOWNS	WEAPONESS RD	2	1		1	F		WAPOL	WAPOL	5	Y	Source from DFES&WAPOL, WAPOL in footprint, DFES out on road, auto-select
AMELIA HEIGHTS SHOPPING CENTRE/ AMELIA HEIGHTS	207 JONES STREET, BALCATTA	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
MORLEY MARKETS	238 WALTER RD, MORLEY	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
CENTRO GALLERIA/ GALLERIA	CORNER COLLIER & WALTER ROAD, MORLEY	4	2		2		LG		LG	6	Y	Source from DFES&WAPOL&LG, LG&WAPOL in footprint, DFES(2 points, same location) out on road, decided by rule
SOUTH LAKE SHOPPING CENTRE/ SOUTH LAKE	CORNER SOUTH LAKE DRIVE & BERRIGAN DRIVE, SOUTH LAKE	3	1	1	1	F		LG	LG	6	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL in cadastre, DFES out on road, auto-select
HERDSMAN SHOPPING CENTRE/ THE HERDSMAN SHOPPING CENTRE	1-9 FLYNN STREET, CHURCHLANDS	2	1	1		F		LG	LG	6	Y	Source from WAPOL&LG, LG in footprint, WAPOL in cadastre, auto-select
SHENTON VILLAGE SHOPPING CENTRE/ SHENTON VILLAGE	ONSLOW ROAD, SHENTON PARK	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
BAYVIEW/ BAYVIEW CENTRE	STIRLING HIGHWAY, CLAREMONT	2	1	1			LG		LG	4	N(should auto select, but here decided by rule)	Source from DFES&LG, DFES in footprint, LG in cadastre, should auto-select DFES, but choose LG, wrong (might because LG point is very close to footprint, intersect result as in footprint)
CLAREMONT/ CLAREMONT SHOPPING CENTRE/ CLAREMONT QUARTER	303 H STIRLING HWY, CLAREMONT	3	1	2		F		DFES	DFES	4	N	Source from DFES(2 points, different location)&WAPOL, 1 DFES in footprint, 1DFES&WAPOL in cadastre, auto-select (but 1 DFES point name is not matched, not sure how involved)
STAMMERS ARCADE	273 CANNING HWY	2	2				WAPOL		WAPOL	5	Y(same point, but bit complicate to be conflated)	Source from DFES&WAPOL, both in footprint, decided by rule
MAGNOLIA SHOPPING CENTRE	161 AMAZON DR, BEECHBORO	2		2			LG		LG	3	Y	Source from WAPOL&LG, both in cadastre, decided by rule
BEECHBORO SQUARE ALTONE PARK/ ALTONE PARK	161 ALTONE RD, BEECHBORO	3	2		1		LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&WAPOL in footprint, DFES out on road, decided by rule
HOCKING/ HOCKING SHOPPING CENTRE	21 EAST RD	2	2				WAPOL		WAPOL	4	Y	Source from WAPOL&DFES, both in footprint, decided by rule
BOULEVARD PLAZA/ BOULEVARD PLAZA SHOPPING CENTRE	9 MOOLANDA BVD, KINGSLEY	3		3			LG		LG	3	Y	Source from DFES&LG&WAPOL, all in cadastre, decided by rule
MERRIWA PLAZA SHOPPING CENTRE/ MERRIWA PLAZA	BALTIMORE PARADE, MERRIWA	2	1	1		F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, auto-select
BELRIDGE CITY/ BELRIDGE	36 GWENDOLINE DR, BELDON	3		3			IG		LG	3	Y	Source from DFES&LG&WAPOL, all in cadastre, decided by rule
THE MARKET PLACE/ THE MARKET PLACE SHOPPING CENTRE	CORNER PARKVIEW DRIVE & ILLAWARRA CRESENT, BALLAJURA	3	2	1			LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
HAMILTON HILL/ HAMILTON HILL SHOPPING PLAZA	43-45 ROCKINGHAM ROAD, HAMILTON HILL	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
LIVINGSTON MARKET PLACE/ LIVINGSTON MARKETPLACE	RANFORD ROAD, CANNING VALE	2	1		1	F		LG	LG	6	Y	Source from DFES&LG, LG in footprint, DFES out on road intersection, auto-select
WESTFIELD/ WESTFIELD HAROLD KING CENTRE	131 WESTFIELD RD, CAMILLO	2		2			LG		LG	3	Y	Source from DFES&LG, both in cadastre, decided by rule
CARINE GLADES SHOPPING CENTRE/ CARINE GLADES	485 BEACH ROAD, DUNCRAIG	3	3				LG		LG	5	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
DUNCRAIG VILLAGE SHOPPING CENTRE/ DUNCRAIG VILLAGE	8-14 BURRAGAH WAY, DUNCRAIG	3	1	2		F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint, DFES&WAPOL in cadastre, auto-select
THE VILLAGE SHOPPING CENTRE/ THE VILLAGE	120 WITTENOOM RD, HIGH WYCOMBE	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
WESTFIELD CAROUSEL/ CAROUSEL	1382 ALBANY HIGHWAY, CANNINGTON	3	1	2		F		LG	LG	5	Y	Source from DFES(2 points, same location)&LG, LG in footprint, DFES in cadastre, auto-select
FORRESTFIELD FORUM/ FORRESTFIELD FORUM & MARKETPLACE	STRELITZIA AVENUE, FORRESTFIELD	3	3				LG		LG	5	Y	Source from DFES(2points, same location)&LG, all in footprint, decided by rule
PRIMEWEST NORTHLANDS/ PRIMEWEST	WANNEROO RD & AMELIA ST, BALCATTA	2			2		DFES		DFES	1	Y(same point, but bit complicate to be conflated)	2 points from DFES, same location
MUNDARING VILLAGE SHOPPING CENTRE/ MUNDARING VILLAGE	7025 GREAT EASTERN HIGHWAY, MUNDARING	3		3			LG		LG	3	Y	Source from DFES&LG&WAPOL, all in cadastre, decided by rule
MUNDARING MALL	7025 H GREAT EASTERN HWY, MUNDARING	2	1	1		F		DFES	DFES	3	Y	Source from DFES&WAPOL, DFES in footprint, WAPOL in cadastre, auto-select
MARMION VILLAGE/ MARMION	SHEPPARD WAY, MARMION	2	1	1		F		LG	LG	5	Y(same point, but bit complicate to be conflated)	Source from DFES&LG, LG in footprint, DFES in cadastre, auto-select
FORREST PLAZA SHOPPING CENTRE/ FORREST PLAZA/ FORREST PLAZA	63 FORREST RD	3	1	2		F		WAPOL	WAPOL	4	Y(LG address available)	Source from DFES&LG&WAPOL, WAPOL in footprint, LG&DFES in cadastre, auto-select
MOSMAN HEIGHTS/ MOSMAN HEIGHTS SHOPPING CENTRE	112-114 WELLINGTON STREET, MOSMAN PARK	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
QUINNS VILLAGE SHOPPING CENTRE/ QUINNS VILLAGE	121 QUINNS ROAD, QUINNS ROCK	3	1	1	1	F		LG	LG	5	Y	Source from DFES&LG&WAPOL, LG in footprint WAPOL in cadastre, DFES out on road, auto-select
STOCKLAND BULL CREEK/ STOCKLAND BULLCREEK	CORNER SOUTH STREET & BENNINGFIELD ROAD, BULL CREEK	2	1		1	F		LG	LG	6	Y(same point, but bit complicate to be conflated)	Source from DFES&LGL, LG in footprint , DFES out on road, auto-select
GLENDALOUGH VILLAGE	2-4 JON SANDERS DRIVE, GLENDALOUGH	2	2				LG		LG	6	Y(same point, but bit complicate to be conflated)	Source from DFES&LGL, both in footprint , decided by rule
THOMSON BAY SETTLEMENT SHOPS	, ROTTNEST ISLAND	2	2				LG		LG	5	Y(? Address not complete)	2 points from LG, in different footprint, not sure how to decide between the two
SAMSON/ SAMSON SHOPPING CENTRE/ SAMSON SHOPPING CENTRE	40 MCCOOMBE AVENUE, SAMSON	3	2		1		LG		LG	6	Y	Source from DFES&LG&WAPOL, LG&WAPOL in footprint, DFES out on road, decided by rule

Conflated point name	Conflated address	Multi sources	Inside footprint	Inside cadastre	Outside	Auto-selected	Selected by Rule	Location source	Address source	Weight	Corretness	Comment
DARLING RIDGE SHOPPING CENTRE/ DARLING RIDGE	309 MORRISON ROAD, SWAN VIEW	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
EDGEWATER SHOPPING CENTRE/ EDGEWATER	1 WISTERIA PARADE, EDGEWATER	2	2				LG		LG	5	Y(same point, but bit complicate to be conflated)	Source from DFES&LG, both in footprint, decided by rule
GREENWOOD KINGSLEY PLAZA	120 H COCKMAN RD, GREENWOOD	2	1	1		F		DFES	DFES	3	Y(same point, but bit complicate to be conflated)	Source from DFES&WAPOL, DFES in footprint, WAPOL in cadastre, auto-select
NEWPARK/ NEW PARK SHOPPING CENTRE	MARANGAROO DRIVE, GIRRAWHEEN	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
OCEAN REEF SHOPPING CENTRE/ OCEAN REEF	82 MARINA DRIVE, OCEAN REEF	3	3				LG		LG	5	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
PORT KENNEDY/ STARGATE PORT KENNEDY	49 H CHELMSFORD AV, PORT KENNEDY	2	2				DFES		DFES	3	Y	2 points from DFES, same location, both in footprint
ST CLAIR/ STARGATE ST CLAIR	49 H CHELMSFORD AV, PORT KENNEDY	2	2				DFES		DFES	3	Y	2 points from DFES, same location, both in footprint
STARGATE SAINT CLAIR	49 CHELMSFORD AV, PORT KENNEDY	2		2			LG		LG	3	Y	Source from LG&WAPOL, both in cadastre, decided by rule
BALLAJURA CITY SHOPPING CENTRE/ BALLAJURA CITY	IIIAWARRA CRESENT & KINGFISHER AVENUE, BALLAJURA	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
LYNWOOD VILLAGE/ LYNWOOD VILLAGE SHOPPING CENTRE/ LYNWOOD VILLAGE SHOPPING CENTRE	4-12 LYNWOOD AVENUE, LYNWOOD	3	2	1			LG		LG	6	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint, WAPOL in cadastre, decided by rule
SECRET HARBOUR	420 SECRET HARBOUR BVD, SECRET HARBOUR	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
LAKESIDE JOONDALUP SHP CTR/ LAKESIDE JOONDALUP	420 JOONDALUP DR	2	2				WAPOL		WAPOL	4	Y	Source from DFES&WAPOL, both in footprint, decided by rule
BURRENDAH SHOPPING CENTRE/ BURRENDAH	61-71 APSLEY ROAD, WILLETTON	3	1	1	1	F		LG	LG	6	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL in cadastre, DFES out on road, auto-select
NORTH PERTH PLAZA	391 FITZGERALD STREET, NORTH PERTH	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
WOODLAKE VILLAGE SHOPPING CENTRE/ WOODLAKE VILLAGE	SUNRAY CIRCLE & WOODLAKE BOULEVARD, ELLENBROOK	2	1	1		F		LG	LG	5	Y	Source from DFES&LG, LG in footprint, DFES in cadastre, auto-select
MIAMI PLAZA SHOPPING CENTRE/ MIAMI PLAZA	OLD COAST ROAD, FALCON	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
FALCON SHOPPING CENTRE/ FALCON	2-6 BAROY STREET, FALCON	3	2	1			LG		LG	5	Y(location & address wrong in reality, it is a	Source from DFES&LG&WAPOL, LG&DFES in footprint (2 different one), WAPOL in cadastre, decided by rule
BICTON SHOPPING CENTRE/ BICTON	17 PEMBROKE STREET, BICTON	3	1	1	1	F		LG	LG	6	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL in cadastre, DFES out on road, auto-select
BASSENDEAN VILLAGE	2 WEST RD, BASSENDEAN	2		1	1	C		LG	LG	3	Y	Source from DFES&LG, LG in cadastre, DFES out on road, auto-select
MADDINGTON VILLAGE/ MADDINGTON VILLAGE SHOPPING CENTRE	WESTFIELD STREET, MADDINGTON	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
MURRAY LAKES SHOPPING CENTRE/ MURRAY LAKES	126-136 SOUTH YUNDERUP ROAD, SOUTH YUNDERUP	3	2	1			LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&DFES in footprint , WAPOL in cadastre, decided by rule
CRAIGIE PLAZA	15 PERILYA ROAD, CRAIGIE	3	3				LG		LG	5	Y	Source from DFES&LG&WAPOL, all in footprint, decided by rule
WINTHROP/ WINTHROP VILLAGES SHOPPING CENTRE	CORNER SOMERVILLE BOULEVARD & JACKSON AVENUE, WINTHROP	2		1	1	C			LG	4	Y	Source from DFES&LG, LG in cadastre, DFES out on road, auto-select
GWELUP PLAZA	707 H NORTH BEACH RD, GWELUP	2	1	1		F		DFES	DFES	4	Y	Source from DFES&WAPOL, DFES in footprint , WAPOL in cadastre, auto-select
DORIC ST/ DORIC STREET SHOPPING CENTRE	1-11 DORIC STREET, SCARBOROUGH	2	1		1	F		LG	LG	6	Y	Source from DFES&LG, LG in footprint, DFES out on road, auto-select
LANGFORD VILLAGE SUPERMARKET/ LANGFORD VILLAGE	LANGFORD AVENUE, LANGFORD	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
TIMBERLANE SHOPPING CENTRE/ TIMBERLANE	497 H BEECHBORO RD N, BEECHBORO	2	1	1		F		DFES	DFES	4	Y	Source from DFES&WAPOL, DFES in footprint , WAPOL in cadastre, auto-select
COOLIBAH PLAZA/ COOLIBAH PLAZA SHOPPING CENTRE	132 COOLIBAH DRIVE, GREENWOOD	3	2	1			LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&WAPOL in footprint , DFES in cadastre, decided by rule
COCKBURN SHOPPING CENTRE/ COCKBURN	CARRINGTON ST	2		1	1	C		WAPOL	WAPOL	3	Y	Source from DFES&WAPOL, WAPOL in cadastre, DFES out on road, auto-select
WATTELUP SHOPPING CENTRE/ WATTLEUP SHOPPING CENTRE	1048 ROCKINGHAM ROAD, WATTLEUP	2	1	1		F		LG	LG	5	Y	Source from LG&WAPOL, LG in footprint , WAPOL in cadastre, auto-select
PHOENIX PARK	ROCKINGHAM RD	2	2				WAPOL		WAPOL	5	Y	Source from DFES&WAPOL, both in footprint , decided by rule
HALLS HEAD SHOPPING VILLAGE/ HALLS HEAD SHOPPING VILLAGE SHOPPING CENTRE	18 PEELWOOD PDE	2	2				WAPOL		WAPOL	4	Y	Source from DFES&WAPOL, both in footprint , decided by rule
CENTRO HALLS HEAD/ HALLS HEAD	14 GUAVA WAY, HALLS HEAD	4	3	1			LG		LG	5	Y	Source from DFES(2 points, same location)&LG&WAPOL, LG&DFES in footprint , WAPOL in cadastre, decided by rule
CORFIELD SHOPPING CENTRE/ CORFIELD	288-292 CORFIELD STREET, GOSNELLS	3	3				LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&WAPOL in footprint , DFES in another footprint, decided by rule
LESMURDIE VILLAGE SHOPPING CENTRE/ LESMURDIE VILLAGE/ SANDERSON ROAD LESMURDIE VILLAGE SHOPPING CENTRE	35 SANDERSON ROAD, LESMURDIE	3	3				LG		LG	5	Y	Source from DFES&LG&WAPOL, all in footprint , decided by rule
MOUNT CLAREMONT/ MOUNT CLAREMONT SHOPPING CENTRE/ MOUNT CLAREMOUNT VILLAGE	39 ASQUITH STREET, MOUNT CLAREMONT	3	2		1		LG		LG	4	Y	Source from DFES&LG&WAPOL, LG&WAPOL in cadastre , DFES out on road, decided by rule
MAYLANDS PARK/ MAYLANDS PARK SHOPPING CENTRE	GUILDFORD ROAD, MAYLANDS	2	2				LG		LG	6	Y	Source from DFES&LG, both in footprint, decided by rule
NOLLAMARA SHOPPING CENTRE/ NOLLAMARA	55-67 NOLLAMARA AVENUE, NOLLAMARA	3	1	1	1	F		LG	LG	6	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL in cadastre , DFES out on road, auto-select
RIVERTON FORUM	2 WILLERI DR, PARKWOOD	3		2	1		LG		LG	4	Y	Source from DFES&LG&WAPOL, LG&WAPOL in cadastre , DFES out on road, decided by rule
CHAMPION DRIVE/ CHAMPION DRIVE SHOPPING CENTRE	CHAMPION DRIVE, SEVILLE GROVE	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
COOLBELLUP/ COOLBELLUP SHOPPING CENTRE/ COOLBELLUP SHOPPING CENTRE	CORNER COOLBELLUP & CORDELIA AVENUE, COOLBELLUP	3	1	1	1	F		LG	LG	6	Y	Source from DFES&LG&WAPOL, LG in footprint, WAPOL in cadastre , DFES out on road, auto-select
SWAN VIEW SHOPPING CENTRE/ SWAN VIEW	40-42 MARLBORO ROAD, SWAN VIEW	2	2				LG		LG	5	Y	Source from DFES&LG, both in footprint, decided by rule
GREENWOOD VILLAGE/ GREENWOOD VILLAGE SHOPPING CENTRE	CALECTASIA STREET, GREENWOOD	3	2	1			LG		LG	5	Y	Source from DFES&LG&WAPOL, LA&DFES in footprint, WAPOL in cadastre, decided by rule
BEAUMARIS CITY/ BEAUMARIS CITY SHOPPING CENTRE	62-68 CONSTELLATION DRIVE, OCEAN REEF	3	2		1		LG		LG	5	Y	Source from DFES&LG&WAPOL, LG&WAPOL in footprint, DFES out on road, decided by rule
DOG SWAMP SHOPPING CENTRE/ DOG SWAMP	WANNEROO ROAD, YOKINE	3	3				LG		LG	6	Y	Source from DFES&LG&WAPOL, all in footprint , decided by rule
RIVERDRIVE VILLAGE SHOPPING CENTRE	477 RIVERTON DR, RIVERTON	2		2			LG		LG	4	Y	Source from LG&WAPOL, both in cadastre , decided by rule
JOONDALUP SHOPPING CENTRE	80 GRAND BVD, JOONDALUP	2		2			LG		LG	3	Y	Source from WAPOL&LG, both in cadastre, decided by rule

APPENDIX C – RULES DEFINITIONS

I. Read source data into application:

1. Read in a POI has SourceLayer as "Landgate", classification code is known, infer its class, subtype, domain and classification code:

PointsOfInterest(?p), POIDomain(?dom), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Name(?dom, ?dn), Name(?type, ?tn), Name(?cls, ?cn), iCode(?dom, ?ic), Classification(?p, ?c), stringEqualIgnoreCase(?c, ?ic), SourceLayer(?p, ?l), stringEqualIgnoreCase(?l, "Landgate") -> iClass(?p, ?cn), iType(?p, ?tn), iDomain(?p, ?dn), iCode(?p, ?ic)

2. Read in a POI has SourceLayer as "WAPOL", PoiDom value is known, infer its class, subtype, domain and classification code:

PointsOfInterest(?p), POIDomain(?dom), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Name(?dom, ?dn), Name(?type, ?tn), Name(?cls, ?cn), iCode(?dom, ?ic),PoiDom(?p, ?d), stringEqualIgnoreCase(?d, ?dn), SourceLayer(?p, ?l), stringEqualIgnoreCase(?l, "WAPOL") -> iClass(?p, ?cn), iType(?p, ?tn), iDomain(?p, ?dn), iCode(?p, ?ic)

3. Read in a POI has SourceLayer as "WAPOL", PoiDom value is known, infer its class, subtype, domain and classification code:

PointsOfInterest(?p), POIDomain(?dom), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Name(?dom, ?dn), Name(?type, ?tn), Name(?cls, ?cn), iCode(?dom, ?ic), NoSpaceName(?dom, ?n), PoiDom(?p, ?d), stringEqualIgnoreCase(?d, ?n), SourceLayer(?p, ?l), stringEqualIgnoreCase(?l, "WAPOL") -> iClass(?p, ?cn), iType(?p, ?tn), iDomain(?p, ?dn), iCode(?p, ?ic)

4. Read in a POI has SourceLayer as "DFES", Domain value is known, infer its class, subtype, domain and classification code:

PointsOfInterest(?p), POIDomain(?dom), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Name(?dom, ?dn), Name(?type, ?tn), Name(?cls, ?cn), iCode(?dom, ?ic), Domain(?p, ?d), NoSpaceName(?dom, ?n), stringEqualIgnoreCase(?d, ?n), SourceLayer(?p, ?l), stringEqualIgnoreCase(?l, "DFES") -> iClass(?p, ?cn), iType(?p, ?tn), iDomain(?p, ?dn), iCode(?p, ?ic)

5. Read in a POI has SourceLayer as "DFES", Domain value is known, infer its class, subtype, domain and classification code:

PointsOfInterest(?p), POIDomain(?dom), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Name(?cls, ?cn), Name(?type, ?tn), Name(?dom, ?dn), iCode(?dom, ?ic), Domain(?p, ?d), stringEqualIgnoreCase(?d, ?dn), SourceLayer(?p, ?l), stringEqualIgnoreCase(?l, "DFES") -> iClass(?p, ?cn),iType(?p, ?tn), iDomain(?p, ?dn), iCode(?p, ?ic)

6. Read in a POI has SourceLayer as "OSM", Type value is known, infer its class, subtype, domain and classification code:

PointsOfInterest(?p), POIDomain(?dom), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Name(?dom, ?dn), Name(?type, ?tn), Name(?cls, ?cn), iCode(?dom, ?ic), Type(?p, ?t), containsIgnoreCase(?dn, ?t), SourceLayer(?p, ?l), stringEqualIgnoreCase(?l, "OSM") -> iClass(?p, ?cn), iType(?p, ?tn), iDomain(?p, ?dn), iCode(?p, ?ic)

7. Read in a POI has SourceLayer as "SLIP", Type value, classification code is known, infer its class, subtype, domain and classification code:

PointsOfInterest(?p), POIDomain(?dom), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Name(?cls, ?cn), Name(?type, ?tn), Name(?dom, ?dn), iCode(?dom, ?ic), Type(?p, ?t), containsIgnoreCase(?dn, ?t), SourceLayer(?p, ?l), stringEqualIgnoreCase(?l, "SLIP") -> iClass(?p, ?cn), iType(?p, ?tn), iDomain(?p, ?dn), iCode(?p, ?ic),

II. Infer whether two POIs have the same name:

8. Compare two POIs, if their feature ID are different, but Name string is equal when ignore case, infer them has same name:

PointsOfInterest(?p1), PointsOfInterest(?p2), Fid(?p1, ?f1), Fid(?p2, ?f2), iName(?p1, ?n1), iName(?p2, ?n2), notEqual(?f1, ?f2), stringEqualIgnoreCase(?n1, ?n2) -> sameNameAs(?p1, ?p2)

9. Compare two POIs, if their feature ID are different, the iName are not empty, when ignoring case, one string contains the other, infer them has same name:
PointsOfInterest(?p1), PointsOfInterest(?p2), Fid(?p1, ?f1), Fid(?p2, ?f2), iName(?p1, ?n1), iName(?p2, ?n2), notEqual(?f1, ?f2), notEqual(?n1, ""), notEqual(?n2, ""), containsIgnoreCase(?n1, ?n2) -> sameNameAs(?p1, ?p2)

10. Compare two POIs, if their feature ID are different, the iName are not empty, when ignoring case, one string contains the other, infer them has same name:
PointsOfInterest(?p1), PointsOfInterest(?p2), Fid(?p1, ?f1), Fid(?p2, ?f2), iName(?p1, ?n1), iName(?p2, ?n2), notEqual(?f1, ?f2), notEqual(?n1, ""), notEqual(?n2, ""), containsIgnoreCase(?n2, ?n1), -> sameNameAs(?p1, ?p2)

11. Compare two POIs, if their feature ID are different, the StemMetaphonePrimary are the same when ignoring case, infer them has same name:
PointsOfInterest(?p1), PointsOfInterest(?p2), Fid(?p1, ?f1), Fid(?p2, ?f2), StemMetaphonePrimary(?p1, ?n1), StemMetaphonePrimary(?p2, ?n2), notEqual(?f1, ?f2), stringEqualIgnoreCase(?n1, ?n2) -> sameNameAs(?p1, ?p2)

III. Get iName value from different sources with different attribute name:

12. A POI from SourceLayer "Landgate", if Name not empty, infer Name as iName:
PointsOfInterest(?p), Name(?p, ?n), SourceLayer(?p, ?l), notEqual(?n, ""), stringEqualIgnoreCase(?l, "Landgate") -> iName(?p, ?n)

13. A POI from SourceLayer "Landgate", if DisplayName not empty, infer DisplayName as iName:
PointsOfInterest(?p), DisplayName(?p, ?n), SourceLayer(?p, ?l), notEqual(?n, ""), stringEqualIgnoreCase(?l, "Landgate") -> iName(?p, ?n)

14. A POI from SourceLayer "Landgate", if FeatureText not empty, infer FeatureText as iName:
PointsOfInterest(?p), FeatureText(?p, ?n), SourceLayer(?p, ?l), notEqual(?n, ""), stringEqualIgnoreCase(?l, "Landgate") -> iName(?p, ?n)

15. A POI from SourceLayer "WAPOL", if Name not empty, infer Name as iName:

PointsOfInterest(?p), Name(?p, ?n), SourceLayer(?p, ?l), notEqual(?n, ""), stringEqualIgnoreCase(?l, "WAPOL") -> iName(?p, ?n)

16. A POI from SourceLayer "DFES", if Name not empty, infer Name as iName:

PointsOfInterest(?p), Name(?p, ?n), SourceLayer(?p, ?l), notEqual(?n, ""), stringEqualIgnoreCase(?l, "DFES") -> iName(?p, ?n)

17. A POI from SourceLayer "SLIP", if Name not empty, infer Name as iName:

PointsOfInterest(?p), Name(?p, ?n), SourceLayer(?p, ?l), notEqual(?n, ""), stringEqualIgnoreCase(?l, "SLIP") -> iName(?p, ?n)

18. A POI from SourceLayer "OSM", if Name not empty, infer FeatureText as iName:

PointsOfInterest(?p), Name(?p, ?n), SourceLayer(?p, ?l), notEqual(?n, ""), stringEqualIgnoreCase(?l, "OSM") -> iName(?p, ?n)

19. Replace names with street acronym ‘ST’ with ‘STREET’:

PointsOfInterest(?p1), iName(?p1, ?n), replace(?x, ?n, " ST ", " STREET ") -> iName(?p1, ?x)

20. Replace names with centre acronym ‘CT’ with ‘CENTRE’:

PointsOfInterest(?p1), iName(?p1, ?n), replace(?x, ?n, "CTR", "CENTRE") -> iName(?p1, ?x)

IV. Assign Weight value:

21. If a POI within a footprint, assign the Weight" value as "2"

PointsOfInterest(?p1), FootprintId(?p1, ?x), notEqual(?x, "") -> Weight(?p1, 2)

22. If a POI within a cadastre, assign the Weight" value as "1"

PointsOfInterest(?p1), CadastreId(?p1, ?x), notEqual(?x, "") -> Weight(?p1, 1)

V. Infer classification code from a domain value:

23. Infer classification code for a domain:

POIDomain(?dom), POISubtype(?type), POIClass(?cls), isSubclassOf(?dom, ?type), isSubclassOf(?type, ?cls), Code(?cls, ?strC), Code(?type, ?strT), Code(?dom, ?strD), stringConcat(?str, ?strC, ?strT, ?strD) -> iCode(?dom, ?str)

APPENDIX D – ONTOLOGY DEVELOPED FOR POI CASE STUDY


```xml
<?xml version="1.0"?>
<!DOCTYPE rdf:RDF [
   <!ENTITY owl "http://www.w3.org/2002/07/owl#" >
   <!ENTITY swrl "http://www.w3.org/2003/11/swrl#" >
   <!ENTITY swrlb "http://www.w3.org/2003/11/swrlb#" >
   <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
   <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
   <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
]>
<rdf:RDF xmlns="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#"
     xml:base="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:swrl="http://www.w3.org/2003/11/swrl#"
     xmlns:owl="http://www.w3.org/2002/07/owl#"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:swrlb="http://www.w3.org/2003/11/swrlb#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
   <owl:Ontology rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53"/>
      <!--
   ///////////////////////////////////////////////////////////////////////////////////////
   //
   // Object Properties
   //
   ///////////////////////////////////////////////////////////////////////////////////////
    -->
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasAddress -->
   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasAddress">
      <rdfs:range rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Address"/>
      <rdfs:domain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
   </owl:ObjectProperty>
      <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasLocation -->
   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasLocation">
      <rdfs:range rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Location"/>
      <rdfs:domain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
   </owl:ObjectProperty>
      <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass -->
   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass">
      <rdfs:range rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
      <rdfs:domain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
      <rdfs:subPropertyOf rdf:resource="&owl;topObjectProperty"/>
   </owl:ObjectProperty>
      <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIDomain -->
   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIDomain">
      <rdfs:range rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
      <rdfs:domain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
   </owl:ObjectProperty>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOISubtype -->
   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOISubtype">
      <rdfs:range rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
      <rdfs:domain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
   </owl:ObjectProperty>
      <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#isSubclassOf -->
   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#isSubclassOf"/
   <!--
   ///////////////////////////////////////////////////////////////////////////////////////
   //
   // Data properties
   //
   ///////////////////////////////////////////////////////////////////////////////////////
    -->
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LGA -->
   <owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LGA">
      <rdfs:comment rdf:datatype="&xsd;string">Local Government Authority</rdfs:comment>
   </owl:DatatypeProperty>
      <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NameID -->
   <owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NameID">
      <rdfs:comment xml:lang="en">Definition:An identifier that equates to a pointer in the Geographic Names Register (database) that
references the feature’s name.
Refer to the “Workspace”, “Index to GEONOMA assignment” for valid attributes.</rdfs:comment>
      <rdfs:domain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
      <rdfs:range rdf:resource="&xsd;string"/>
   </owl:DatatypeProperty>
      <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SRID -->
   <owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SRID">
      <rdfs:range rdf:resource="&xsd;string"/>
   </owl:DatatypeProperty>
      <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SystemNameID -->
   <owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SystemNameID">
      <rdfs:comment xml:lang="en">Definition: Only applicable to the “Hydrography” theme.
A second “NameID” that allows features that have individual names to also have a system name.
For example various named lakes, pools etc. are also part of a hydrographic system (e.g. the
Avon River). This attribute only applies to “WaterLine”, “WaterPolygon” and “WaterPoint”
“Hydrography” feature classes.
Refer to the “Workspace”, “Index to GEONOMA assignment” for valid attributes.</rdfs:comment>
```

```
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TOWN -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TOWN"/>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TopographicGlobalID -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TopographicGlobalID">
    <rdfs:comment xml:lang="en">Definition: For POI features related to Topographic features, this field holds the parent feature's GlobalID.</rdfs:comment>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#address -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#address">
    <rdfs:label xml:lang="en">AddressText</rdfs:label>
    <rdfs:comment xml:lang="en">Definition: Temporary field to hold street number, street name, street type, locality; until a live link is established with the Address Database (ADR) whereby this field will be retired.</rdfs:comment>
    <rdfs:domain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#class_code -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#class_code">
    <rdfs:label>class code</rdfs:label>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#classificationCode -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#classificationCode">
    <rdfs:label xml:lang="en">classificationCode</rdfs:label>
    <rdfs:comment xml:lang="en">Definition: A 6 digit code derived from the combination of Feature Class, Subtype and Domain values toallo
w the reconstruction of the classification system from a flat or text file export. The values in this field are managed automatically but are derived from a feature class number (2 digit), Subtype number (fcSubType – 2 digit) and Domain Value (eg. HospitalPOIType = 07: Psychiatric Hospital)</rdfs:comment>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#domain_code -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#domain_code">
    <rdfs:label>domain code</rdfs:label>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#houseNum -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#houseNum">
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#latitude -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#latitude">
    <rdfs:range rdf:resource="&xsd;decimal"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#locality -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#locality">
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#longitude -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#longitude">
    <rdfs:range rdf:resource="&xsd;decimal"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#matchedPoints -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#matchedPoints"/>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#name -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#name">
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#numType -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#numType">
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadName -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadName">
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadSuffx -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadSuffx">
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadType -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadType">
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#subtype_code -->
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#subtype_code">
    <rdfs:label>subtype code</rdfs:label>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<!--
///////////////////////////////////////////////////////////////////////////////////////
//
// Classes
//
///////////////////////////////////////////////////////////////////////////////////////
 -->
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain -->
```

```
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Address -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Address">
    <owl:equivalentClass>
        <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
                <owl:Class>
                    <owl:intersectionOf rdf:parseType="Collection">
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#houseNum"/>
                            <owl:someValuesFrom rdf:resource="&xsd;string"/>
                        </owl:Restriction>
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#houseNum"/>
                            <owl:maxCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:maxCardinality>
                        </owl:Restriction>
                    </owl:intersectionOf>
                </owl:Class>
                <owl:Class>
                    <owl:intersectionOf rdf:parseType="Collection">
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#locality"/>
                            <owl:someValuesFrom rdf:resource="&xsd;string"/>
                        </owl:Restriction>
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#locality"/>
                            <owl:maxCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:maxCardinality>
                        </owl:Restriction>
                    </owl:intersectionOf>
                </owl:Class>
                <owl:Class>
                    <owl:intersectionOf rdf:parseType="Collection">
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadName"/>
                            <owl:someValuesFrom rdf:resource="&xsd;string"/>
                        </owl:Restriction>
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadName"/>
                            <owl:maxCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:maxCardinality>
                        </owl:Restriction>
                    </owl:intersectionOf>
                </owl:Class>
                <owl:Class>
                    <owl:intersectionOf rdf:parseType="Collection">
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadSuffx"/>
                            <owl:someValuesFrom rdf:resource="&xsd;string"/>
                        </owl:Restriction>
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadSuffx"/>
                            <owl:maxCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:maxCardinality>
                        </owl:Restriction>
                    </owl:intersectionOf>
                </owl:Class>
                <owl:Class>
                    <owl:intersectionOf rdf:parseType="Collection">
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadType"/>
                            <owl:someValuesFrom rdf:resource="&xsd;string"/>
                        </owl:Restriction>
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#roadType"/>
                            <owl:maxCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:maxCardinality>
                        </owl:Restriction>
                    </owl:intersectionOf>
                </owl:Class>
            </owl:unionOf>
        </owl:Class>
    </owl:equivalentClass>
    <rdfs:subClassOf rdf:resource="&owl;Thing"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmenityDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmenityDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmusementDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmusementDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacilityDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacilityDomain">
```

```
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicalAndZoologicalDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicalAndZoologicalDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BridgeDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BridgeDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
<rdfs:comment xml:lang="en">As POI’s these are named features only and judgement needs to be administered in regard to whether the feature constitutes a bridge or tunnel. Bridge features will generally span an obstacle of significance. Examples include; Narrows bridge, Stirling Bridge.</rdfs:comment>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusFacilityDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusFacilityDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CareFacilityDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CareFacilityDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthDomain"/>
<rdfs:comment xml:lang="en">Some aged care facilities have ‘Hostel’ in their name. These are classified as aged care facilities.</rdfs:comment>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ChildCareCentreDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ChildCareCentreDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
<rdfs:comment xml:lang="en">This category currently includes after school care.
Attribute: CommercialType set to not applicable = -98</rdfs:comment>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ClassificationCode -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ClassificationCode">
<owl:equivalentClass>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="&owl;Thing"/>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#classificationCode"/>
<owl:someValuesFrom rdf:resource="&xsd;string"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#classificationCode"/>
<owl:maxCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:maxCardinality>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:intersectionOf>
</owl:Class>
</owl:equivalentClass>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Commercial -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Commercial">
<owl:equivalentClass>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
<owl:Class>
<owl:unionOf rdf:parseType="Collection">
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIDomain"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOISubtype"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass"/>
<owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI"/>
</owl:Restriction>
</owl:unionOf>
</owl:Class>
</owl:intersectionOf>
</owl:Class>
</owl:equivalentClass>
<rdfs:isDefinedBy xml:lang="en">Definition: Service features where the chief aim is profit. (WA)
```

```
Spatial Representation: A single point at the feature's main access point where applicable, otherwise at the feature's central point.</rdfs:isDefinedBy>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Commercial"/>
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityFacilityDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityFacilityDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityService -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityService">
        <owl:equivalentClass>
            <owl:Class>
                <owl:intersectionOf rdf:parseType="Collection">
                    <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
                    <owl:Class>
                        <owl:unionOf rdf:parseType="Collection">
                            <owl:Restriction>
                                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
                                <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceDomain"/>
                            </owl:Restriction>
                            <owl:Restriction>
                                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOISubtype"/>
                                <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceType"/>
                            </owl:Restriction>
                            <owl:Restriction>
                                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIClass"/>
                                <owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServicePOI"/>
                            </owl:Restriction>
                        </owl:unionOf>
                    </owl:Class>
                </owl:intersectionOf>
            </owl:Class>
        </owl:equivalentClass>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType"/>
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityService"/>
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ConsultingAndContractingServiceDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#ConsultingAndContractingServiceDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Defence -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Defence">
        <owl:equivalentClass>
            <owl:Class>
                <owl:intersectionOf rdf:parseType="Collection">
                    <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
                    <owl:Class>
                        <owl:unionOf rdf:parseType="Collection">
                            <owl:Restriction>
                                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
                                <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#DefenceDomain"/>
                            </owl:Restriction>
                            <owl:Restriction>
```

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                <owl:onProperty                rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIClass"/>
                <owl:hasValue                  rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#DefencePOI"/>
              </owl:Restriction>
            </owl:unionOf>
          </owl:Class>
        </owl:intersectionOf>
      </owl:Class>
    </owl:equivalentClass>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility or an area set aside for defence purposes. (Modified ANZLIC)
Spatial Representation: A single point at the feature’s central point or main entrance.</rdfs:isDefinedBy>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceType"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
    <rdfs:comment xml:lang="en">Comment: There are no subtypes associated with these features.</rdfs:comment>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceType -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceType">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Defence"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
    <rdfs:comment xml:lang="en">Comment: There are no subtypes associated with these features.
Domain table provides description.</rdfs:comment>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Education -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Education">
    <owl:equivalentClass>
      <owl:Class>
        <owl:intersectionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
          <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
              <owl:Restriction>
                <owl:onProperty                rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
                <owl:someValuesFrom            rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#EducationDomain"/>
              </owl:Restriction>
              <owl:Restriction>
                <owl:onProperty                rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOISubtype"/>
                <owl:someValuesFrom            rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#EducationType"/>
              </owl:Restriction>
              <owl:Restriction>
                <owl:onProperty                rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIClass"/>
                <owl:hasValue                  rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#EducationPOI"/>
              </owl:Restriction>
            </owl:unionOf>
          </owl:Class>
        </owl:intersectionOf>
      </owl:Class>
    </owl:equivalentClass>
    <rdfs:isDefinedBy xml:lang="en">Definition: A service feature related to the act or process of educating; the imparting or acquisition of
knowledge, skill, etc; systematic instruction or training. (Modified NSW)
Spatial Representation: A single point at the feature’s main entrance or administration building.</rdfs:isDefinedBy>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationType"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationSupportDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationSupportDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationType -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationType">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Education"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain">
    <rdfs:subClassOf                           rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EntertainmentVenueDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EntertainmentVenueDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodServiceDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodServiceDomain">
```

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    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FuelOutletDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FuelOutletDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
    <rdfs:comment xml:lang="en">Comment: Fuel Types to be derived from GEONOMA.
Attribute: CommercialType set to not applicable = -98</rdfs:comment>
  </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GamingDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GamingDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Geographic -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Geographic">
    <owl:equivalentClass>
      <owl:Class>
        <owl:intersectionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
          <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
              <owl:Restriction>
                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
                <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#GeographicDomain"/>
              </owl:Restriction>
              <owl:Restriction>
                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOISubtype"/>
                <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#GeographicType"/>
              </owl:Restriction>
              <owl:Restriction>
                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIClass"/>
                <owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#GeographicPOI"/>
              </owl:Restriction>
            </owl:unionOf>
          </owl:Class>
        </owl:intersectionOf>
      </owl:Class>
    </owl:equivalentClass>
    <rdfs:isDefinedBy xml:lang="en">Definition: Landscape features and places of particular significance to the community. (WA)
Spatial Representation: A single point at the feature’s central point.</rdfs:isDefinedBy>
  </owl:Class>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicType"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicType -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicType">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Geographic"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
    <rdfs:comment xml:lang="en">Comment: Only named features are considered POIs. This feature class is entirely populated and maintained
through the Topographic themes.</rdfs:comment>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Health -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Health">
    <owl:equivalentClass>
      <owl:Class>
        <owl:intersectionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
          <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
              <owl:Restriction>
                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
                <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#HealthDomain"/>
              </owl:Restriction>
              <owl:Restriction>
                <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOISubtype"/>
                <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#HealthType"/>
              </owl:Restriction>
              <owl:Restriction>
```

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                <owl:onProperty                    rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIClass"/>
                <owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthPOI"/>
              </owl:Restriction>
            </owl:unionOf>
          </owl:Class>
        </owl:intersectionOf>
      </owl:Class>
    </owl:equivalentClass>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthType"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthType -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthType">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Health"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hospitality -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hospitality">
    <owl:equivalentClass>
      <owl:Class>
        <owl:intersectionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
          <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
              <owl:Restriction>
                <owl:onProperty                    rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
                <owl:someValuesFrom                rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#HospitalityDomain"/>
              </owl:Restriction>
              <owl:Restriction>
                <owl:onProperty                    rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOISubtype"/>
                <owl:someValuesFrom                rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#HospitalityType"/>
              </owl:Restriction>
              <owl:Restriction>
                <owl:onProperty                    rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIClass"/>
                <owl:hasValue                      rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#HospitalityPOI"/>
              </owl:Restriction>
            </owl:unionOf>
          </owl:Class>
        </owl:intersectionOf>
      </owl:Class>
    </owl:equivalentClass>
    <rdfs:isDefinedBy xml:lang="en">Definition: Features associated especially with tourism, of providing service to patrons including hotel
accommodation, restaurant meals and beverage service. (Modified Macquarie Dictionary)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityType"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
  </owl:Class>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityType -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityType">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hospitality"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Industry -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Industry">
    <owl:equivalentClass>
      <owl:Class>
        <owl:intersectionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
          <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
```

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<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#IndustryDomain"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOISubtype"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#IndustryType"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIClass"/>
<owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#IndustryPOI"/>
</owl:Restriction>
</owl:unionOf>
</owl:Class>
</owl:intersectionOf>
</owl:Class>
</owl:equivalentClass>
<rdfs:isDefinedBy>Definition: Enterprises involved in the manufacturing of goods or materials. (WA)
Spatial Representation: A single point at the feature’s main access point where applicable, otherwise at the feature’s central
point.</rdfs:isDefinedBy>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryType"/>
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryType -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryType">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Industry"/>
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InfrastructureDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InfrastructureDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CommunityServiceDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LegalAndFinancialServiceDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LegalAndFinancialServiceDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
</owl:Class>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LicensedPremisesDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LicensedPremisesDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Location -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Location"/>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MediaAndTelecommunicationDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#MediaAndTelecommunicationDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mining -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mining">
<owl:equivalentClass>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
<owl:Class>
<owl:unionOf rdf:parseType="Collection">
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOIDomain"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#MiningDomain"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#hasPOISubtype"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#MiningType"/>
</owl:Restriction>
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                        <owl:Restriction>
                            <owl:onProperty                        rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass"/>
                            <owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningPOI"/>
                        </owl:Restriction>
                    </owl:unionOf>
                </owl:Class>
            </owl:intersectionOf>
        </owl:Class>
    </owl:equivalentClass>
    <rdfs:isDefinedBy xml:lang="en">Definition: Features whose primary characteristics relate to mining. (Modified ICSM)
Spatial Representation: A single point at the feature’s central point or main entrance.</rdfs:isDefinedBy>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningType"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
    <rdfs:comment xml:lang="en">Domain Not Applicable (-98)</rdfs:comment>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningType -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningType">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mining"/>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
  </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain">
    <rdfs:subClassOf                        rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OutdoorAreaDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OutdoorAreaDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicDomain"/>
  </owl:Class>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorshipDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorshipDomain">
    <rdfs:subClassOf                        rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceDomain"/>
  </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest">
    <rdfs:label xml:lang="en">PointsOfInterest</rdfs:label>
    <owl:equivalentClass>
      <owl:Restriction>
        <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass"/>
        <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
      </owl:Restriction>
    </owl:equivalentClass>
    <rdfs:subClassOf rdf:resource="&owl;Thing"/>
    <rdfs:comment xml:lang="en">Definition: Any place, feature or service that people wish to visit or know the location of, and is of value to the community. (WALIS)
</rdfs:comment>
  </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PostalServiceDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PostalServiceDomain">
    <rdfs:subClassOf                        rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceDomain"/>
    <rdfs:comment xml:lang="en">Comment: All features are to be categorised as Post Office. Other feature types may be added at a later stage.</rdfs:comment>
  </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RacingDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RacingDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
  </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacilityDomain -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacilityDomain">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
  </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Recreation -->
  <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Recreation">
    <owl:equivalentClass>
      <owl:Class>
        <owl:intersectionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
          <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
              <owl:Restriction>
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                    <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIDomain"/>
                    <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
                  </owl:Restriction>
                  <owl:Restriction>
                    <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOISubtype"/>
                    <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
                  </owl:Restriction>
                  <owl:Restriction>
                    <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass"/>
                    <owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationPOI"/>
                  </owl:Restriction>
                </owl:unionOf>
              </owl:Class>
            </owl:intersectionOf>
          </owl:Class>
        </owl:equivalentClass>
    </owl:Class>
        <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POISubtype"/>
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Recreation"/>
    </owl:Class>
        <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RentalAndHireServiceDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RentalAndHireServiceDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetirementEstateDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetirementEstateDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialDomain"/>
        <rdfs:comment xml:lang="en">Attribute: CommercialType set to not applicable = -98</rdfs:comment>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadFacilityDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadFacilityDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacilityDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacilityDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
        <rdfs:comment xml:lang="en"> For Jetties and wharves only named features are included in the POI theme. Eg. Coode St. Jetty, Busselton Jetty, Berth E, Berth 9.</rdfs:comment>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationDomain"/>
    </owl:Class>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Transportation -->
    <owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Transportation">
        <owl:equivalentClass>
          <owl:Class>
            <owl:intersectionOf rdf:parseType="Collection">
              <rdf:Description rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
              <owl:Class>
                <owl:unionOf rdf:parseType="Collection">
                  <owl:Restriction>
                    <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIDomain"/>
                    <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
                  </owl:Restriction>
                  <owl:Restriction>
                    <owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOISubtype"/>
                    <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
                  </owl:Restriction>
                  <owl:Restriction>
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<owl:onProperty rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#hasPOIClass"/>
<owl:hasValue rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationPOI"/>
</owl:Restriction>
</owl:unionOf>
</owl:Class>
</owl:intersectionOf>
</owl:Class>
</owl:equivalentClass>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType -->
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<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Transportation"/>
<rdfs:comment xml:lang="en">No domain table for Tunnel sub type. TransportationType value = not applicable (-98)</rdfs:comment>
</owl:Class>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TunnelDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TunnelDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationDomain"/>
<rdfs:comment xml:lang="en">As POI's these are named features only and judgement needs to be administered in regard to whether the feature constitutes a bridge or tunnel. A tunnel feature references the main Transportation feature as going under an obstacle. Examples include; SwanView rail tunnel, Mt Lawley Subway.
This is a POI classification and is related to the name as an indicator of the perception of the feature which differs to a Topographic interpretation. For example the name 'Mt Lawley Subway' suggests the reference is from the perspective of the road, which passes under the railway.
The POI is the 'Tunnel' feature related to the name component 'subway'. Topographically the railway crosses a bridge but this bridge is not the POI named 'Mt Lawley Subway'.</rdfs:comment>
</owl:Class>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain -->
<owl:Class rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicDomain"/>
</owl:Class>
<!--
///////////////////////////////////////////////////////////////////////////////////////
//
// Individuals
//
///////////////////////////////////////////////////////////////////////////////////////
-->
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Abattoir -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Abattoir">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">37</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A building or place where animals are slaughtered for food. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AboriginalCommunity -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AboriginalCommunity">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceDomain"/>
<domain_code rdf:datatype="&xsd;string">01</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A location at which some form of community (aboriginal) facility operates. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Accommodation -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Accommodation">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityType"/>
<domain_code rdf:datatype="&xsd;string">01</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: Service feature providing short term lodging. (WA)
Spatial Representation: A single point at the feature's main entrance.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AdminEducationalSupport -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AdminEducationalSupport">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationSupportDomain"/>
<domain_code rdf:datatype="&xsd;string">09</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility that provides administration or support to educational facilities. (WA)
This is the default EducationSupportPOIType.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AgedCare -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AgedCare">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CareFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">01</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility that provides lodging and medical care and treatment for aged citizens. (WA)
This is the default for CareFacilityPOIType</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AgedCareDayService -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AgedCareDayService">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain"/>
<domain_code rdf:datatype="&xsd;string">01</domain_code>
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    <rdfs:isDefinedBy xml:lang="en">Definition: Services designed to assist older people to remain independent, live in their own home for as
long as possible, maintain optimum physical and mental health, social connectedness and pursue interests and hobbies. (Aust. Health Directory)
eg. Vincent House, Killara Centre, TAPSS Community Care.</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AirForceBase -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AirForceBase">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceDomain"/>
    <domain_code rdf:datatype="&xsd;string">0001</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An area owned and operated by the government as an Air Force Base. (WA)
This is the default DefenceFacilityType.</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Airport -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Airport">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility, either on land or water, where aircraft can take off and land; usually consists of
hard-surfaced landing strips, a control tower, hangars, and accommodations for passengers and cargo. (ICSM)
This is the default for AviationFacilityPOIType.</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AluminaRefinery -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AluminaRefinery">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An industrial process plant where alumina is refined from the raw ore. (Modified
WIKIPEDIA).</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Ambulance -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Ambulance">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: The facility in which ambulance vehicles and equipment are stationed or intended to be
stationed. (NSW)
This is the default for EmergencyServicePOIType.</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Amenity -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Amenity">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType"/>
    <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Amusement -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Amusement">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
    <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Facilities that offers rides, games, and other forms of entertainment. (WA)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AnimalRefuge -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AnimalRefuge">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility providing a refuge for unwanted, neglected, abandoned, lost or injured animals.
(WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Aquaculture -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Aquaculture">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Land used for the commercial breeding and keeping of aquatic animals or plants in tanks,
ponds and leased areas within natural waterways. (NSW)</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AquaticCentre -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AquaticCentre">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A group of buildings and swimming pools for the purpose of water activities.
(WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Arboretum -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Arboretum">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicalAndZoologicalDomain"/>
    <domain_code rdf:datatype="&xsd;string">12</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A plot of land where different trees or shrubs are grown for study or popular interest.
(Macquarie Dictionary)</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ArmyBase -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ArmyBase">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceDomain"/>
    <domain_code rdf:datatype="&xsd;string">0002</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An area owned and operated by the government as an Army Base. (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>
  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ArtAndCraft -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ArtAndCraft">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Shop selling skilfully created goods of artistic value. (WA)</rdfs:isDefinedBy>
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    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ArtGalleryPublic -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ArtGalleryPublic">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility used as a place set apart for the keeping, exhibition, and study of objects of artistic
interest. (NSW) This is the default CulturalFacilityPOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacility -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacility">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
        <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Services and facilities related to the aviation industry. (WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationService -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationService">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A service whose primary role is to support the aviation industry. Usually located in the
near vicinity of an airport. (WA).</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationTerminal -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationTerminal">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Terminal used by an airline at an airport for the embarking and disembarking of passengers or
freight. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Banking -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Banking">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#LegalAndFinancialServiceDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Commercial venture offering services related to the holding and loaning of money on behalf
of account holders. (WA)
This is the default for LegalAndFinancialServicePOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Battery -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Battery">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A stone crushing works for ore extraction, as used on gold-fields.
(CGNA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Bay -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Bay">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A named bay-like feature. Includes: Bays, Bights, Coves, Entrances, Gulfs, Harbours, Inlets,
Ports and River Mouths.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
        <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Beach -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Beach">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A named beach feature. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BedAndBreakfast -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BedAndBreakfast">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A style of accommodation offered by an inn, hotel, or esp. a private home, consisting of a
room for the night and breakfast the next morning for one inclusive price.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BikeHire -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BikeHire">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RentalAndHireServiceDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A business that provides the temporary use of bicycles for a fee. (WA)
This is the default for RentalAndHireServicePOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BingoHall -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BingoHall">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GamingDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility where Bingo is played. (WA)
This is the default for GamingPOIType</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BirdAndWildlifeSanctuary -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#BirdAndWildlifeSanctuary">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicalAndZoologicalDomain"/>
        <domain_code rdf:datatype="&xsd;string">20</domain_code>
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<rdfs:isDefinedBy xml:lang="en">Definition: A tract of land where birds and wildlife, can breed and take refuge in
safety.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BloodDonorClinic -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BloodDonorClinic">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain"/>
<domain_code rdf:datatype="&xsd;string">02</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility where people have blood drawn for use in transfusions. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BoatAndWaterCraftHire -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BoatAndWaterCraftHire">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RentalAndHireServiceDomain"/>
<domain_code rdf:datatype="&xsd;string">02</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A business that provides the temporary use of water craft for a fee. (WA) eg. Canoe
hire.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BoatLaunching -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BoatLaunching">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">02</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A group of features potentially including launching ramps, jetties, car parks and other
facilities, where boats may be launched. In some cases facilities may be limited. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicGarden -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicGarden">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicalAndZoologicalDomain"/>
<domain_code rdf:datatype="&xsd;string">25</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A large garden usually open to the public where trees, shrubs and plants, typically from many
lands, are grown and studied. (Macquarie Dictionary)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicalAndZoological -->
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<subtype_code rdf:datatype="&xsd;string">02</subtype_code>
<rdfs:isDefinedBy xml:lang="en">Definition: Features pertaining to the preservation, study and display of flora and fauna. (WA)
Spatial Representation: A single point at the feature’s main entrance or at the feature’s central
point.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Brewery -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Brewery">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LicensedPremisesDomain"/>
<domain_code rdf:datatype="&xsd;string">01</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: An establishment for the manufacture of malt liquors, such as beer and ale that is additionally
licensed to serve their wares on site to the public. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Brickworks -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Brickworks">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">03</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A place where bricks are made. (CGNA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Bridge -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Bridge">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
<subtype_code rdf:datatype="&xsd;string">06</subtype_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A structure erected over a depression or obstacle to carry traffic or some facility such as a
pipeline. (ICSM) Spatial Representation: Point Sub Type: A single point at the feature’s central point.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusFacility -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusFacility">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
<subtype_code rdf:datatype="&xsd;string">04</subtype_code>
<rdfs:isDefinedBy xml:lang="en">Definition: Facilities related to the transport of passengers by bus. (WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusInterchange -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusInterchange">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">01</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A connection or terminal point for multiple bus services. (WA)
This is the default for BusFacilityPOIType.</rdfs:isDefinedBy>
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<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusRailInterchange -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusRailInterchange">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">02</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A transfer point between rail and bus services. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CafeAndRestaurant -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CafeAndRestaurant">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodServiceDomain"/>
<domain_code rdf:datatype="&xsd;string">01</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: An establishment where meals are served to customers. A café is usually smaller and less
formal than a restaurant, often with an outdoor section extending onto the footpath. (WA)
This is the default FoodServicePOIType</rdfs:isDefinedBy>
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      <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodService"/>
   </owl:NamedIndividual>
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   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Campsite">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
      <domain_code rdf:datatype="&xsd;string">02</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: An area where a camp has been established or where it would be suitable to establish one; an
area, often provided with amenities, where it is permitted to set up a camp. (CGNA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CarPark -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CarPark">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InfrastructureDomain"/>
      <domain_code rdf:datatype="&xsd;string">01</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: An area designated for the parking of motor vehicles. (CGNA)
This is the default InfrastructurePOIType.</rdfs:isDefinedBy>
      <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Infrastructure"/>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CaravanAndTouristPark -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CaravanAndTouristPark">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
      <domain_code rdf:datatype="&xsd;string">03</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: An area in which caravans are, or can be, parked, or where caravan type accommodation can
be obtained. Domestic facilities may be provided. (CGNA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CareFacility -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CareFacility">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthType"/>
      <subtype_code rdf:datatype="&xsd;string">03</subtype_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A facility providing a specialised residential care service.
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CargoTerminal -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CargoTerminal">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacilityDomain"/>
      <domain_code rdf:datatype="&xsd;string">01</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A facility where good and produce are stored/received when transported by ship. Usually
consists of hard-surfaced areas, sheds etc. (WA)
This is the default for ShippingFacilityPOIType.</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Casino -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Casino">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GamingDomain"/>
      <domain_code rdf:datatype="&xsd;string">02</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A facility for gambling and other entertainment. (WA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Cave -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Cave">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
      <domain_code rdf:datatype="&xsd;string">06</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A naturally formed, subterranean open area or chamber. (ICSM)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CementPlant -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CementPlant">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
      <domain_code rdf:datatype="&xsd;string">29</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A facility where raw materials are mixed, crushed and kiln fired to produce cement.
(WA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CemetaryAndCrematorium -->
   <owl:NamedIndividual                                    rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CemetaryAndCrematorium">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
      <domain_code rdf:datatype="&xsd;string">03</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: Facilities for the incineration or burying of the dead. (WA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CharityAndVolunteerOrganisation -->
   <owl:NamedIndividual                                    rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CharityAndVolunteerOrganisation">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain"/>
      <domain_code rdf:datatype="&xsd;string">02</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: An institution established to help the needy. (WA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ChildCareCentre -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ChildCareCentre">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
      <subtype_code rdf:datatype="&xsd;string">07</subtype_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A facility that provides daytime and after school supervision and recreation for children.
(WA) Spatial Representation: A single point at the feature’s central point or main entrance.</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ChildHealthCentre -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ChildHealthCentre">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain"/>
      <domain_code rdf:datatype="&xsd;string">03</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A service staffed by registered nurses with qualifications in child and family health providing
a range of services in partnership with parents and carers of babies and young children up to the age of 4 years. (Department of Health WA). This
is the default HealthServicePOIType.</rdfs:isDefinedBy>
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</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Children -->
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    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility that specialises in the medical care and treatment of sick or injured children. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Church -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Church">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorshipDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A building for public Christian worship. (WA)
This is the default for PlaceOfWorshipPOIType.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Cinema -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Cinema">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EntertainmentVenueDomain"/>
    <domain_code rdf:datatype="&xsd;string">07</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A venue for motion-picture screening. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CitizensAdviceBureau -->
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    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Agency providing an information and referral service in the areas of legal advice and mediation. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ClothingAndAccessories -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ClothingAndAccessories">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CoachStation -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CoachStation">
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    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A stopping place to set down or pick up passengers for long distance coach services. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CombinedGeneralEmergency -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CombinedGeneralEmergency">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility that can provide both general medical care and emergency medical care and treatment of sick or injured persons.(Modified NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CombinedPrimarySecondary -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CombinedPrimarySecondary">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used for full-time primary and secondary instruction of children, typically aged 6 to 17. (Modified NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI">
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    <class_code rdf:datatype="&xsd;string">07</class_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Service features where the chief aim is profit. (WA)
Spatial Representation: A single point at the feature’s main access point where applicable, otherwise at the feature’s central point.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunicationTower -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunicationTower">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InfrastructureDomain"/>
    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A relatively tall structure used for transmitting and/or receiving electronic communication signals.(DIGEST)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityCentre -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityCentre">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility that services as a meeting place for a group of people with a common interest. Also includes Halls and Civic Centres. (Modified Web)
This is the default CommunityFacilityPOIType.</rdfs:isDefinedBy>
</owl:NamedIndividual>
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</owl:NamedIndividual>
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      <rdfs:isDefinedBy xml:lang="en">Definition: A service that is provided for the benefit of the public. (WA)
Spatial Representation: A single point at the feature’s main access point where applicable, otherwise at the feature’s central point.</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ConferenceAndExhibitionCentre -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ConferenceAndExhibitionCentre">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EntertainmentVenueDomain"/>
      <domain_code rdf:datatype="&xsd;string">01</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A venue designed to accommodate trade shows and to host public and private business and social events. Will include several smaller rooms for lectures, meetings and conferences. (WA)
This is the default for EntertainmentVenuePOIType</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Conservatory -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Conservatory">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
      <domain_code rdf:datatype="&xsd;string">02</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A conservatory is also another name for a large greenhouse where plants are cultivated.
(Modified WIKIPEDIA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Consulate -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Consulate">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain"/>
      <domain_code rdf:datatype="&xsd;string">01</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A diplomatic building that serves as the residence or workplace of a consul. (Web)
This is the default for GovernmentPOIType.</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ConsultingAndContractingService -->
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      <rdfs:isDefinedBy xml:lang="en">Definition: Commercial entities that provide professional advice Definition and information to clients on a particular area of expertise. (WA)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
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   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ContainerTerminal -->
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      <rdfs:isDefinedBy xml:lang="en">Definition: A facility where container are stored/received when transported by ship. Usually consists of hard-surfaced areas, sheds etc. (WA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ControlTower -->
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      <domain_code rdf:datatype="&xsd;string">08</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: An elevated tower within an airport used by air traffic controllers for the visual observation of aircraft. (Web)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CounsellingAndPsychology -->
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      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain"/>
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      <rdfs:isDefinedBy xml:lang="en">Definition: Services providing professional guidance in resolving personal conflicts and emotional problems.
(WA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CourtAndTribunal -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CourtAndTribunal">
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      <rdfs:isDefinedBy xml:lang="en">Definition: A place where a judge, magistrate, committee or board adjudicate in a particular matter of law.
(WA)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Crater -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Crater">
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      <rdfs:isDefinedBy xml:lang="en">Definition: A bowl shaped natural depression with steep slopes at the rim, formed by volcanic activity or meteor impact. (AUSLIG)</rdfs:isDefinedBy>
   </owl:NamedIndividual>
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   </owl:NamedIndividual>
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      <rdfs:isDefinedBy xml:lang="en">Definition: A barrier of earth and/or rock, concrete or masonry constructed to form a reservoir for water storage purposes or to raise the water level. (ICSM)</rdfs:isDefinedBy>
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<rdfs:isDefinedBy xml:lang="en">Definition: A surgical facility at a hospital or in a doctor's rooms for procedures which do not involve
overnight hospitalisation of the patients. (Macquarie Dictionary)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefencePOI -->
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<class_code rdf:datatype="&xsd;string">10</class_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility or an area set aside for defence purposes. (Modified ANZLIC)
Spatial Representation: A single point at the feature’s central point or main entrance.</rdfs:isDefinedBy>
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<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefencePracticeArea -->
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<rdfs:isDefinedBy xml:lang="en">Definition: A facility that specialises in dental care. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DentalHealth -->
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<domain_code rdf:datatype="&xsd;string">06</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: Professional services dealing with the prevention, diagnosis, and treatment of diseases of the teeth, gums, and related structures of the mouth and including the repair or replacement of defective teeth.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Depot_Bus -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Depot_Bus">
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<rdfs:isDefinedBy xml:lang="en">Definition: A facility used for the storage of buses. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Depot_Maintenance -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Depot_Maintenance">
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<domain_code rdf:datatype="&xsd;string">21</domain_code>
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</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Depot_Storage -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Depot_Storage">
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<domain_code rdf:datatype="&xsd;string">25</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definitioin: A facility used for the storage of materials. (WA)</rdfs:isDefinedBy>
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<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DisabledCare -->
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<rdfs:isDefinedBy xml:lang="en">Definition: A facility that specialises in accommodating and providing medical care and treatment for disabled people. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
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<domain_code rdf:datatype="&xsd;string">02</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definiton: An establishment for distilling alcoholic liquors that is additionally licensed to serve their wares
on site to the public. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DogRacing -->
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<rdfs:isDefinedBy xml:lang="en">Definition: A facility prepared for a competition of speed between dogs. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationPOI -->
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Spatial Representation: A single point at the feature’s main entrance or administration building.</rdfs:isDefinedBy>
</owl:NamedIndividual>
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationSupport -->
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        <rdfs:isDefinedBy xml:lang="en">Definition: A service that is related to the act or process of educating; providing support services and additional facilities to assist students and increase educational opportunities. (WA)
Spatial Representation: A single point at the feature’s main entrance or administration building.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Emergency -->
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        <rdfs:isDefinedBy xml:lang="en">Definition: A facility that can provide emergency medical care and treatment of sick or injured persons.(Modified NSW)</rdfs:isDefinedBy>
    </owl:NamedIndividual>
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    </owl:NamedIndividual>
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        <rdfs:isDefinedBy xml:lang="en">Definition: Service that searches for and procures staff on behalf of businesses. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EntertainmentVenue -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EntertainmentVenue">
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        <rdfs:isDefinedBy xml:lang="en">Definition: A place providing for diversion or amusement, especially an exhibition or performance of some kind. . (modified Macquarie Dictionary)
Spatial Representation: A single point at the feature’s main entrance or at the feature’s central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>
    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EquestrianCentre -->
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        <rdfs:isDefinedBy xml:lang="en">Definition: An area set aside for equestrian activities. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>
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    </owl:NamedIndividual>

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        <LGA rdf:datatype="&xsd;string">BAYSWATER</LGA>
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      <LGA rdf:datatype="&xsd;string">BAYSWATER</LGA>
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   </owl:NamedIndividual>

   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Factory -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Factory">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
      <domain_code rdf:datatype="&xsd;string">23</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: A building(s) usually with equipment where goods are manufactured).(ICSM)
This is the default for IndustrialFacilityPOIType.</rdfs:isDefinedBy>
   </owl:NamedIndividual>

   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Farmstay -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Farmstay">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
      <domain_code rdf:datatype="&xsd;string">04</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Accommodation service provided on a working farm. Farming activities form an attraction for
guests.</rdfs:isDefinedBy>
   </owl:NamedIndividual>

   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FastFood -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FastFood">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodServiceDomain"/>
      <domain_code rdf:datatype="&xsd;string">02</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: An establishment that provides food that is prepared in quantity by a standardised method and
can be dispensed quickly at inexpensive restaurants for eating there or elsewhere. (WA)</rdfs:isDefinedBy>
      <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodService"/>
   </owl:NamedIndividual>

   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FederalGovernmentAgency -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#FederalGovernmentAgency">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain"/>
      <domain_code rdf:datatype="&xsd;string">03</domain_code>
      <rdfs:isDefinedBy xml:lang="en">Definition: Agency funded by the Federal Government to perform tasks in the National interest.
(WA)</rdfs:isDefinedBy>
      <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Government"/>
   </owl:NamedIndividual>

   <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FireAndRescue_Career -->
   <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FireAndRescue_Career">
      <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
      <domain_code rdf:datatype="&xsd;string">02</domain_code>
```

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        <rdfs:isDefinedBy xml:lang="en">Definition: A facility in which fire fighting and rescue vehicles and equipment is stationed or intended to
be stationed, generally to service urban communities. The facility is manned by full time career fire fighting staff. (Modified
NSW)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FireAndRescue_Volunteer -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#FireAndRescue_Volunteer">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility in which fire fighting and rescue vehicles and equipment is stationed or intended to
be stationed, generally to service urban communities. Potentially an unmanned (volunteer) based facility. (Modified NSW)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodService -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodService">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityType"/>
        <subtype_code rdf:datatype="&xsd;string">02</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Service feature providing meals to patrons. (WA)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
        <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityPOI"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Footbridge -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Footbridge">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BridgeDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A structure spanning and providing passage over a depression or obstacle specifically for use
by pedestrians.(WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FuelOutlet -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FuelOutlet">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
        <subtype_code rdf:datatype="&xsd;string">05</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A commercial business that specialises in the dispensing of motor vehicle fuel – diesel,
petroleum and gas. (WA)
Spatial Representation: A single point at the feature’s central point.</rdfs:isDefinedBy>
        <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Gaming -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Gaming">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
        <subtype_code rdf:datatype="&xsd;string">06</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility where people can play games of chance for money or other stakes. (WA)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#General -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#General">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility used for medical care and treatment of sick or injured persons. (Modified NSW)
This is the default for HospitalPOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicPOI -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicPOI">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        <class_code rdf:datatype="&xsd;string">09</class_code>
        <rdfs:isDefinedBy xml:lang="en">Definition Landscape features and places of particular significance to the community. (WA)
Spatial Representation: A single point at the feature’s central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GoldRefinery -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GoldRefinery">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">22</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility used to refine gold, removes impurities, to designated purity specifications.
(Modified Web)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GolfCourse -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GolfCourse">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">05</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An area set aside for playing golf. (ICSM)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Gorge -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Gorge">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">16</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A landform which is more than usually deep and narrow, with steep walls.
(CGNA)</rdfs:isDefinedBy>
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    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Government -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Government">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType"/>
        <subtype_code rdf:datatype="&xsd;string">05</subtype_code>
        <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServicePOI"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GrainStorage -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GrainStorage">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">32</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility including all necessary equipment and buildings, where grains can be stored.
(WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HardwareAndGardenSupplies -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#HardwareAndGardenSupplies">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
        <domain_code rdf:datatype="&xsd;string">08</domain_code>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthCentre -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthCentre">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain"/>
        <domain_code rdf:datatype="&xsd;string">07</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Community health service provided through a network of public, private and non- government
services to help people with most common health problems. (Dept of Health WA) Examples include: Belmont Community Health Centre,
Coolgardie Health Centre, Avon and Central Primary Health Service.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthPOI -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthPOI">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        <class_code rdf:datatype="&xsd;string">03</class_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A service assisting in the prevention, treatment, and management of illness and the
preservation of mental and physical well-being through the services offered by the medical and allied health professions.
Spatial Representation: A single point at the feature’s main entrance or administration building.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthService -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthService">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthType"/>
        <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility that provides specialised medical care. (WA)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Heliport -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Heliport">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A place designated for the landing and takeoff of helicopters, including its buildings and
facilities.(DIGEST)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hill -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hill">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">19</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A small portion of the earth’s surface elevated above its surroundings and of sufficient
significance to be named. (Modified CGNA)
This is the default for LandFeaturePOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Homestead -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Homestead">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceDomain"/>
        <domain_code rdf:datatype="&xsd;string">21</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A main residence on a horticultural or agricultural farm. (CGNA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HorseRacing -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HorseRacing">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RacingDomain"/>
        <domain_code rdf:datatype="&xsd;string">10</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility prepared for a competition of speed between horses. (WA)
This is the default for RacingPOIType</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hospice -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hospice">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CareFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
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        <rdfs:isDefinedBy xml:lang="en">Definition: A hospital for terminally ill patients. (Macquarie Dictionary)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hospital -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hospital">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthType"/>
        <subtype_code rdf:datatype="&xsd;string">02</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility in which sick or Definition injured persons are given medical or surgical treatment. (Modified ICSM)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityPOI -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityPOI">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        <class_code rdf:datatype="&xsd;string">01</class_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Features associated especially with tourism, of providing service to patrons including hotel accommodation, restaurant meals and beverage service. (Modified Macquarie Dictionary)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hostel -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hostel">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CareFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A residential care facility for troubled and/or homeless people. (WA) Examples include:
Allawah Grove Hostel, Lentara Men&apos;s Hostel, St Bartholomew&apos;s House.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hotel -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Hotel">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
        <domain_code rdf:datatype="&xsd;string">05</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility that provides lodging, usually on a short-term basis. (Modified WIKIPEDIA)
This is the default AccommodationPOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HouseAndOfficeSupplies -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HouseAndOfficeSupplies">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
        <domain_code rdf:datatype="&xsd;string">09</domain_code>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacility -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacility">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryType"/>
        <subtype_code rdf:datatype="&xsd;string">05</subtype_code>
        <rdfs:isDefinedBy>Definition: A facility for the manufacturing of goods or materials. (WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryPOI -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustryPOI">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        <class_code rdf:datatype="&xsd;string">08</class_code>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Infrastructure -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Infrastructure">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType"/>
        <subtype_code rdf:datatype="&xsd;string">06</subtype_code>
        <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServicePOI"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Institution -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Institution">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationType"/>
        <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility for the act or process of educating; the imparting or acquisition of knowledge, skill, etc; systematic instruction or training. (NSW)
Spatial Representation: A single point at the feature’s main entrance or administration building.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Insurance -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Insurance">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LegalAndFinancialServiceDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A commercial entity providing coverage by contract whereby for an agreed payment one party agrees to indemnify or guarantee another against loss by a specified contingency or peril. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IntensiveAnimalProduction -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IntensiveAnimalProduction">
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    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">28</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility for the breeding and keeping of livestock (intensive production). (Modified NSW)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Investment -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Investment">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LegalAndFinancialServiceDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Commercial entities aiming to gain wealth for their clients through the purchase of appreciating assets or by providing advice on such purchases. Also those entities involved in providing funds and capital. (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IronOreProcessor -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IronOreProcessor">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">05</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A plant where iron is produced from iron ore (Smelting (extractive metallurgy) process). (Modified WIKIPEDIA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Island -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Island">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An area of dry or relatively dry land entirely surrounded by water. Includes Islet. (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IslandGroup -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IslandGroup">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A group or cluster of Islands, Island Group features includes Archipelago (CGNA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Jetty -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Jetty">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A structure projecting into a body of water for use as a promenade or as a platform
alongside which vessels may be secured for loading and unloading passengers and cargo. (AUSLIG)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Kindergarten -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Kindergarten">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used for the tuition of young children (usually under the age of 5) prior to preschool. (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_1012 -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_1012">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <latitude rdf:datatype="&xsd;decimal">-31.896438</latitude>
    <longitude rdf:datatype="&xsd;decimal">115.896342</longitude>
    <address rdf:datatype="&xsd;string">238 Walter Rd, Morley</address>
    <name rdf:datatype="&xsd;string">MORLEY MARKETS</name>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShoppingCentre"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_2081 -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_2081">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <latitude rdf:datatype="&xsd;decimal">-32.051461</latitude>
    <longitude rdf:datatype="&xsd;decimal">115.749773</longitude>
    <address rdf:datatype="&xsd;string">39 Adelaide St, Fremantle</address>
    <name rdf:datatype="&xsd;string">FREMANTLE SHOPPING CENTRE</name>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShoppingCentre"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_2135 -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_2135">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <latitude rdf:datatype="&xsd;decimal">-32.087046</latitude>
    <address rdf:datatype="&xsd;string">106 Ranford Rd, Canning Vale</address>
    <longitude rdf:datatype="&xsd;decimal">115.916536</longitude>
    <name rdf:datatype="&xsd;string">CANNING VALE PETROL / AUTOGAS STATION</name>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FuelOutlet"/>
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    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NotApplicable"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_3518 -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_3518">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <latitude rdf:datatype="&xsd;decimal">-32.051389</latitude>
    <longitude rdf:datatype="&xsd;decimal">115.749722</longitude>
    <locality rdf:datatype="&xsd;string">FREMANTLE</locality>
    <LGA rdf:datatype="&xsd;string">FREMANTLE, CITY OF</LGA>
    <name rdf:datatype="&xsd;string">Medicare</name>
    <address rdf:datatype="&xsd;string">Shop 12, 39 Adelaide Street, Fremantle</address>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#FederalGovernmentAgency"/>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Government"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_6791 -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LG_6791">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <latitude rdf:datatype="&xsd;decimal">-32.059774</latitude>
    <longitude rdf:datatype="&xsd;decimal">115.746619</longitude>
    <address rdf:datatype="&xsd;string">34 Mews Rd, Fremantle</address>
    <name rdf:datatype="&xsd;string">CAR PARK FCC NO. 31B</name>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CarPark"/>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Infrastructure"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LPGPlant -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LPGPlant">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">06</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A plant where liquid petroleum gas is refined from crude oil. (Modified
WIKIPEDIA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Lake -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Lake">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A body or water surrounded by land. (DIGEST)
This is the default for WaterFeaturePOIType.</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeature -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeature">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicType"/>
    <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Topographic features of significance whose primary characteristics relate to the land surface
of the Earth. (WA)
Spatial Representation: A single point at the feature’s central point or main access point.</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandingGround -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandingGround">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AviationFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">05</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Landing area with clearly marked runway but no airport facility. (modified
AUSLIG)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Legal -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Legal">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#LegalAndFinancialServiceDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Commercial services related to the administration of justice. (WA) eg. Barristers and
solicitors.</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LegalAndFinancialService -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#LegalAndFinancialService">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
    <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Commercial services related to the administration of the law and financial matters.
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Library -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Library">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used as a place set apart to contain books and other literary material for reading,
study and reference. (NSW)</rdfs:isDefinedBy>
  </owl:NamedIndividual>
```

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    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LicensedPremises -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LicensedPremises">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityType"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility whose primary business is the sale and supply of alcoholic beverages to the public
for consumption on the premises. Such premises are required to hold a suitable license issued by the Department of Racing, Gaming and Liquor.
(WA)
Spatial Representation: Point Sub Type: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Lighthouse -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Lighthouse">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InfrastructureDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A building or structure housing a light used as a navigation aid to shipping.
(AUSLIG)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Liquor -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Liquor">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LocalGovernmentAgency -->
    <owl:NamedIndividual                                   rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#LocalGovernmentAgency">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Agency funded by the local ratepayers to provide services and amenities to the community.
(WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Lookout -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Lookout">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A place on a high vantage point, especially a mountain, from which one can admire the view.
(WA)
This is the default for TourismPOIType</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MarineRescueService -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MarineRescueService">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
        <domain_code rdf:datatype="&xsd;string">05</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A service specialising in search and rescue operations in the marine environment. Generally
staffed by volunteers. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MarshallingYard -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MarshallingYard">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An area of land with one or more sidings or spur lines to allow trains to be parked, serviced,
assembled an/or unloaded.(ICSM)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MediaAndTelecommunication -->
    <owl:NamedIndividual                                   rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#MediaAndTelecommunication">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
        <subtype_code rdf:datatype="&xsd;string">02</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Commercial entities related to the transmission of information either by electromagnetic
signals or more traditional forms such as magazines and newspapers. (WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MeteorologicalStation -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MeteorologicalStation">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">05</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility designed for making meteorological observations. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mine -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mine">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningType"/>
        <subtype_code rdf:datatype="&xsd;string">01</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An excavation made in the earth for the purpose of extracting ores, coal, precious stones,
minerals, etc.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MineralSandProcessingPlant -->
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    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MineralSandProcessingPlant">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">30</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility for extracting minerals from excavated mineral sand. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningCentre -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningCentre">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A town/place in the community which acts as the centre for mine coordination/management for the surrounding region. (WA).</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningPOI -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MiningPOI">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        <class_code rdf:datatype="&xsd;string">11</class_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Features whose primary characteristics relate to mining. (Modified ICSM)
Spatial Representation: A single point at the feature’s central point or main entrance.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mosque -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mosque">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorshipDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A Muslim place of public worship with at least one minaret (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Motel -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Motel">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A roadside hotel facility typically having rooms adjacent to an outside parking area. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MotorRacing -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MotorRacing">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RacingDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility prepared for a competition of speed between motor vehicles. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mountain -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Mountain">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">07</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A natural elevation of the earth surface rising more or less abruptly from the surrounding level and attaining an altitude which, relatively to the adjacent elevation, is impressive or notable. Generally the height of a mountain is considered at least 300m from foot to summit. (Modified Oxford English Dictionary)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MulticulturalCentre -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MulticulturalCentre">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility provided for specific ethnic groups. (WA) For example: Macedonian Community Centre.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Museum -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Museum">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility for the keeping, exhibiting, and study of objects of scientific, artistic, and historical interest. (NSW)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NamedBuilding -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NamedBuilding">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InfrastructureDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Prominent building named in such a way that the building is commonly referred to by its name.
(WA). Examples include: Dumas House, Axa Centre, Central Park, Bankwest Tower, QV1, etc.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NavalBase -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NavalBase">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#DefenceDomain"/>
        <domain_code rdf:datatype="&xsd;string">0003</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An area owned and operated by the government as a Naval Base. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>
```

```
<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NewspaperPublishing -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NewspaperPublishing">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MediaAndTelecommunicationDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A business organization producing a publication issued at regular and usually close intervals, esp. daily or weekly, and commonly containing news, comment, features, and advertising. (WA). eg. Sunday Times</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NickelRefinery -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NickelRefinery">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">07</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An industrial process plant where nickel is refined from the raw ore. (Modified WIKIPEDIA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NickelSmelter -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NickelSmelter">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">08</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A plant where nickel is produced from the raw ore (Smelting (extractive metallurgy) process). (Modified WIKIPEDIA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NotApplicable -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NotApplicable">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIDomain"/>
    <domain_code rdf:datatype="&xsd;string">00</domain_code>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NursingPost -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NursingPost">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HealthServiceDomain"/>
    <domain_code rdf:datatype="&xsd;string">08</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Centres offering basic health care and treatment. Qualified nurses staff these centres and doctors visit on a routine basis. Types of service available vary but can include the following: Coronary Care · Emergency · Home and Community Care · Medical, General · Outpatients · Pathology · Pharmacy · Paediatrics · School Health · x- ray examination (Dept of Health WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Observatory -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Observatory">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">07</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility designed for making observations of astronomical or other natural phenomena. Excludes meteorological observations (Modified NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OffRoadVehicleArea -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OffRoadVehicleArea">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">21</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An area set aside for the use of vehicles not licensed for road use. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OilProcessingPlant -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OilProcessingPlant">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">09</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An industrial process plant where oil is further processed to produce other produces. (Modified WIKIPEDIA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OilRefinery -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OilRefinery">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">10</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An industrial process plant where crude oil is processed and refined into useful petroleum products. (WIKIPEDIA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Organisation -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Organisation">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType"/>
    <subtype_code rdf:datatype="&xsd;string">07</subtype_code>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Other -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Other">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorshipDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Any place used for religious congregation and practice by religions other than those listed above. (WA) For example: a Vihara (Buddhist), a Mondir (Hindu).</rdfs:isDefinedBy>
</owl:NamedIndividual>
```

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    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OtherRacing -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OtherRacing">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RacingDomain"/>
        <domain_code rdf:datatype="&xsd;string">16</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility prepared for a competition of speed between competitor types not specifically listed
in this domain table. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Other_ -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Other_">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RentalAndHireServiceDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A business that offers goods for hire not otherwise specified in this domain.
(WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OutdoorArea -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OutdoorArea">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
        <subtype_code rdf:datatype="&xsd;string">04</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An area set aside for recreational act Definition ivities and/or for the preservation of a cultural
or natural resource. (WA)
Spatial Representation: A single point at the feature’s central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_10358 -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_10358">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
        <latitude rdf:datatype="&xsd;decimal">-31.90040016</latitude>
        <longitude rdf:datatype="&xsd;decimal">115.8879013</longitude>
        <houseNum rdf:datatype="&xsd;string">131</houseNum>
        <address rdf:datatype="&xsd;string">131 WALTER RD</address>
        <locality rdf:datatype="&xsd;string">DIANELLA</locality>
        <numType rdf:datatype="&xsd;string">H</numType>
        <roadType rdf:datatype="&xsd;string">RD</roadType>
        <name rdf:datatype="&xsd;string">SIZZLER STEAK-SEAFOOD-SALAD</name>
        <roadName rdf:datatype="&xsd;string">WALTER</roadName>
        <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CafeAndRestaurant"/>
        <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodService"/>
        <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityPOI"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_12283 -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_12283">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
        <latitude rdf:datatype="&xsd;decimal">-32.05144316</latitude>
        <longitude rdf:datatype="&xsd;decimal">115.7497759</longitude>
        <houseNum rdf:datatype="&xsd;string">39</houseNum>
        <address rdf:datatype="&xsd;string">39 ADELAIDE ST</address>
        <roadName rdf:datatype="&xsd;string">ADELAIDE</roadName>
        <locality rdf:datatype="&xsd;string">FREMANTLE</locality>
        <name rdf:datatype="&xsd;string">FREMANTLE WINE CELLARS AND PROVIDORES</name>
        <numType rdf:datatype="&xsd;string">H</numType>
        <roadType rdf:datatype="&xsd;string">ST</roadType>
        <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI"/>
        <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Liquor"/>
        <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_15179 -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_15179">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
        <roadType rdf:datatype="&xsd;string"></roadType>
        <latitude rdf:datatype="&xsd;decimal">-32.08709999</latitude>
        <houseNum rdf:datatype="&xsd;string">110</houseNum>
        <address rdf:datatype="&xsd;string">110 RANFORD RD</address>
        <longitude rdf:datatype="&xsd;decimal">115.9165</longitude>
        <name rdf:datatype="&xsd;string">CALTEX STARSHOP LIVINGSTON</name>
        <locality rdf:datatype="&xsd;string">CANNING VALE</locality>
        <numType rdf:datatype="&xsd;string">H</numType>
        <roadName rdf:datatype="&xsd;string">RANFORD</roadName>
        <roadType rdf:datatype="&xsd;string">RD</roadType>
        <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI"/>
        <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FuelOutlet"/>
        <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#NotApplicable"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_5126 -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_5126">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
        <latitude rdf:datatype="&xsd;decimal">-32.05976999</latitude>
        <longitude rdf:datatype="&xsd;decimal">115.74662</longitude>
        <name rdf:datatype="&xsd;string">CAR PARK FCC NO. 31B</name>
        <locality rdf:datatype="&xsd;string">FREMANTLE</locality>
        <roadName rdf:datatype="&xsd;string">MEWS</roadName>
```

```xml
    <address rdf:datatype="&xsd;string">MEWS RD</address>
    <roadType rdf:datatype="&xsd;string">RD</roadType>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CarPark"/>
    <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServicePOI"/>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Infrastructure"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_68544 -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_68544">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <rdfs:label>POL_1436</rdfs:label>
    <latitude rdf:datatype="&xsd;decimal">-31.89817</latitude>
    <longitude rdf:datatype="&xsd;decimal">115.89162</longitude>
    <houseNum rdf:datatype="&xsd;string">194</houseNum>
    <address rdf:datatype="&xsd;string">194 WALTER RD W</address>
    <numType rdf:datatype="&xsd;string">H</numType>
    <name rdf:datatype="&xsd;string">HUNGRY JACKS MORLEY</name>
    <locality rdf:datatype="&xsd;string">MORLEY</locality>
    <roadType rdf:datatype="&xsd;string">RD</roadType>
    <roadSuffx rdf:datatype="&xsd;string">W</roadSuffx>
    <roadName rdf:datatype="&xsd;string">WALTER</roadName>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FastFood"/>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#FoodService"/>
    <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalityPOI"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_7901 -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POL_7901">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
    <latitude rdf:datatype="&xsd;decimal">-31.8963896</latitude>
    <longitude rdf:datatype="&xsd;decimal">115.8964573</longitude>
    <houseNum rdf:datatype="&xsd;string">238</houseNum>
    <address rdf:datatype="&xsd;string">238 WALTER RD W</address>
    <numType rdf:datatype="&xsd;string">H</numType>
    <name rdf:datatype="&xsd;string">IGA MORLEY</name>
    <locality rdf:datatype="&xsd;string">MORLEY</locality>
    <roadType rdf:datatype="&xsd;string">RD</roadType>
    <roadSuffx rdf:datatype="&xsd;string">W</roadSuffx>
    <roadName rdf:datatype="&xsd;string">WALTER</roadName>
    <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI"/>
    <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
    <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Supermarket"/>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PWCTakeOffPoint -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PWCTakeOffPoint">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">24</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Place where personal water craft are permitted access to the shore for launching and
embarking/disembarking of passengers and equipment. (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ParkReserve -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ParkReserve">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OutdoorAreaDomain"/>
    <domain_code rdf:datatype="&xsd;string">08</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An area set aside for recreation, sport or preservation of a cultural or natural resource.
(ICSM)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Pass -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Pass">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">21</domain_code>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PassengerTerminal -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PassengerTerminal">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility where passengers embark/disembark when transported by ship or ferry. Usually
consists of hard-surfaced areas, sheds etc. (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Peak -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Peak">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">22</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: The pointed summit of a hill or mountain. (CGNA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Peninsula -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Peninsula">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LandFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">05</domain_code>
```

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    <rdfs:isDefinedBy xml:lang="en">Definition: A named landform where the land extends into a waterbody with water on three sides. Includes: Cape, Peninsula and Spit. (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Pharmacy -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Pharmacy">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
    <domain_code rdf:datatype="&xsd;string">07</domain_code>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PicnicArea -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PicnicArea">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OutdoorAreaDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A tract of land reserved for day picnic purposes, with constructed fire-places and other facilities. (CGNA)
This is the default for OutdoorAreaPOIType</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Place -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Place">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicType"/>
    <subtype_code rdf:datatype="&xsd;string">03</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A place at which there is or was human occupation or activity. (CGNA)
Spatial Representation: A single point at the feature’s central point.</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorship -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorship">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType"/>
    <subtype_code rdf:datatype="&xsd;string">08</subtype_code>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Playground -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Playground">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OutdoorAreaDomain"/>
    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An area used for outdoor play or recreation, esp. by children, containing recreational equipment such as slides and swings. (WA)
</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PoliceStation -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PoliceStation">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
    <domain_code rdf:datatype="&xsd;string">06</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used as the headquarters of a police force, or of a branch of a police force. (NSW)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PoliticalParty -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PoliticalParty">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A group of citizens sharing an ideological viewpoint organised to exercise or seek power in the governmental or public affairs of a nation, state, municipality (WA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Pool -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Pool">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">05</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A small body of still or standing water, permanent or temporary, often in the bed of an intermittent watercourse, and sometimes spring fed, chiefly one of natural formation. (CGNA)</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PostOffice -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PostOffice">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PostalServiceDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility whose primary business is to handle and service mail and associated supplies of equipment. (NSW)
This is the default PostalServicePOIType.</rdfs:isDefinedBy>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PostalService -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PostalService">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommunityServiceType"/>
    <subtype_code rdf:datatype="&xsd;string">09</subtype_code>
  </owl:NamedIndividual>

  <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerStation_FossilFuel -->
  <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerStation_FossilFuel">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">11</domain_code>
```

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<rdfs:isDefinedBy xml:lang="en">Definition: The building(s) and equipment necessary for the generation of electric power using fossil fuel fired generators. For example coal, diesel or natural gas. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerStation_Hydro -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerStation_Hydro">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">33</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: The building(s), structures and equipment necessary for the generation of electric power using pressure from water stored in a dam. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerStation_Other -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerStation_Other">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">34</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: The building(s), structures and equipment necessary for the generation of electric power using any means other than is specified in this domain. For example, solar, tidal, wave, wind or any other means. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerSubStation -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PowerSubStation">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">12</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility, along a power line route, in which electric current is transformed and/or distributed. DIGEST)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Preschool -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Preschool">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
<domain_code rdf:datatype="&xsd;string">04</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility used for the tuition of young children prior to school age, usually children age of five.
(Modified NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrimarySchool -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrimarySchool">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
<domain_code rdf:datatype="&xsd;string">03</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility used for full-time primary instruction of children, typically aged 6 to 11. (Modified NSW)
This is the default InstitutionPOIType.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Printing -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Printing">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">24</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility involved in publishing - printing is an industrial process for reproducing copies of texts
and images, typically with ink on paper using a printing press. (Modified Web)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrisonAndDetentionCentre -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrisonAndDetentionCentre">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain"/>
<domain_code rdf:datatype="&xsd;string">17</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A building(s) in which persons are legally committed to, while awaiting trail, processing or for punishment. (Modified CGNA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrivateOrganisationAccommodationFacility -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrivateOrganisationAccommodationFacility">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
<domain_code rdf:datatype="&xsd;string">07</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility providing accommodation services to members of a group or organisation. Examples
include – Apex Holiday Centre, WA War Blind Soldiers Camp and Swan Brewery Holiday Cottages.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Psychiatric -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Psychiatric">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalDomain"/>
<domain_code rdf:datatype="&xsd;string">07</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility used for the psychiatric treatment of mentally ill persons. (NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PumpStation -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PumpStation">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">27</domain_code>
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        <rdfs:isDefinedBy xml:lang="en">Definition: A facility to move solids, liquids or gases by means of pressure or suction. (DIGEST)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Racing -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Racing">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
        <subtype_code rdf:datatype="&xsd;string">05</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A prepared ground provided to support competitive racing. (WA)
Spatial Representation: A single point at the feature’s main entrance.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RadioBroadcasting -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RadioBroadcasting">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MediaAndTelecommunicationDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Location of the offices and studios from which programs are produced and broadcast for listening via radio. (WA). eg. 96fm.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacility -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacility">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
        <subtype_code rdf:datatype="&xsd;string">03</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Facilities related to the transport of passengers and goods via train. (WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RangersOffice -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RangersOffice">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain"/>
        <domain_code rdf:datatype="&xsd;string">07</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Building or location from which a ranger manages a park or reserve. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Rapid -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Rapid">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">09</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An area of broken, fast flowing water in a watercourse, where the slope of the bed increases (but without a prominent break of slope which might result in a waterfall), or where a gently dipping bar of harder rock outcrops.(AUSLIG)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationPOI -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationPOI">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        <class_code rdf:datatype="&xsd;string">04</class_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility or an Definition area set aside for recreational or sporting activity. (Modified ICSM)
Spatial Representation: A single point at the feature’s main access point where applicable, otherwise at the feature’s central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Rehabilitation -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Rehabilitation">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalDomain"/>
        <domain_code rdf:datatype="&xsd;string">08</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility that specialises in the medical care associated with post treatment rehabilitation.(WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RentalAndHireService -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RentalAndHireService">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
        <subtype_code rdf:datatype="&xsd;string">04</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Commercial entities that provide the temporary use of an item for a fee. (WA)
Spatial Representation: A single point at the feature’s main access point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Reservoir -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Reservoir">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A body of water collected and stored behind a constructed barrier for some specific use. (AUSLIG)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RestArea -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RestArea">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Locations provided to allow drivers to take a break on long journeys and reduce fatigue. Facilities provided vary between rest areas. (WA)
This is the default for RoadFacilityPOIType.</rdfs:isDefinedBy>
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</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
    <subtype_code rdf:datatype="&xsd;string">06</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Commercial entities that sell goods to the public. (WA)
Spatial Representation: A single point at the feature’s main access point.</rdfs:isDefinedBy>
    <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialPOI"/>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetirementEstate -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetirementEstate">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CommercialType"/>
    <subtype_code rdf:datatype="&xsd;string">08</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility that provides accommodation to retired persons. (WA)
Spatial Representation: A single point at the feature’s central point or main entrance.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadFacility -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadFacility">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
    <subtype_code rdf:datatype="&xsd;string">05</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Features associated with travel by road. (WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadTrainAssemblyArea -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#RoadTrainAssemblyArea">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">36</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Designated area where multiple trailers are organised and joined to form road trains.
Usually outside a built up area. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Sawmill -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Sawmill">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">13</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An establishment in which timber is sawn into planks, boards, etc. by machinery.
(CGNA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ScenicFeature -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ScenicFeature">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain"/>
    <domain_code rdf:datatype="&xsd;string">01</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition; A naturally occurring feature of significance to tourist. Differs from TouristSite as a result of a
lack of facilities. (WA) ie. The feature is the POI rather than the facility. An example is Dog Rock in Albany.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SecondarySchool -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SecondarySchool">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
    <domain_code rdf:datatype="&xsd;string">05</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used for full-time secondary institution of children, typically aged 12 to 17.
(NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SelfCateredAccommodation -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#SelfCateredAccommodation">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
    <domain_code rdf:datatype="&xsd;string">08</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Service providing holiday lodging in a house, or apartment styled room that includes kitchen
facilities. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SewageTreatmentPlant -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SewageTreatmentPlant">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">15</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used to treat sewage.(Modified NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShipYard -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShipYard">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">14</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility for manufacturing and repairing vessels. (NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacility -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacility">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
```

```xml
        <subtype_code rdf:datatype="&xsd;string">02</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Facilities rel Definition ated to the transport of passengers and goods via ship or ferry. (WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShootingComplex -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShootingComplex">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">11</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility set aside for shooting practice or contests. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShoppingCentre -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShoppingCentre">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: The concentration of retailing and other service activities at a nodal and accessible point. (CGNA)</rdfs:isDefinedBy>
        <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Showground -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Showground">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmusementDomain"/>
        <domain_code rdf:datatype="&xsd;string">12</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A tract of land with pavilion(s) and arena(s) for the exhibition and display of livestock and produce. (CGNA)
This is the default for AmusementPOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Siding -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Siding">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A point on a railway designated as a stopping place to set down or pick up freight or passengers in a non regular schedule. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SiliconSmelter -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SiliconSmelter">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">16</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A plant where silicon is produced from the raw ore (Smelting (extractive metallurgy) process). (Modified WIKIPEDIA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SocialClub -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SocialClub">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain"/>
        <domain_code rdf:datatype="&xsd;string">05</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A formal association of people with similar interests. (WA)
This is the default for OrganisationPOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Sound -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Sound">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
        <domain_code rdf:datatype="&xsd;string">10</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A relatively long arm of the sea. Forming a channel between and island and the mainland, or connecting two larger bodies of water, as a sea and the ocean, or two parts of the same body, but usually wider and more extensive than a strait. (CGNA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SpecialSchool -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SpecialSchool">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility used for the education of children with special needs. (NSW)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SpecialisedFood -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SpecialisedFood">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
        <domain_code rdf:datatype="&xsd;string">05</domain_code>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SpecialisedStudies -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SpecialisedStudies">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
        <domain_code rdf:datatype="&xsd;string">10</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility used for providing specialised teaching (curriculum). (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacility -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacility">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
```

```
<subtype_code rdf:datatype="&xsd;string">07</subtype_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A place where sporting activities are conducted. (WA)
Spatial Representation: A single point at the feature’s main entrance or at the feature’s central point.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportsCentre -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportsCentre">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">15</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A group of interconnected buildings and other facilities designed for the playing of various sports. (NSW)
This is the default for SportingFacilityPOIType</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportsClub -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportsClub">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">03</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A single or group of buildings and other facilities where a group of members meet to play a specific sport. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportsStadium -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportsStadium">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">14</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: An enclosed athletic or sports ground with tiers of seats for spectators (CGNA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Spring -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Spring">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
<domain_code rdf:datatype="&xsd;string">03</domain_code>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StateEmergencyService -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StateEmergencyService">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
<domain_code rdf:datatype="&xsd;string">07</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility for the purpose of administering the state emergency services. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StateEmergencyServiceVolunteerUnits -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StateEmergencyServiceVolunteerUnits">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
<domain_code rdf:datatype="&xsd;string">08</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A facility in which vehicles and equipment are stationed for rescue and emergency use
by SES volunteer crews. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StateGovernmentAgency -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StateGovernmentAgency">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain"/>
<domain_code rdf:datatype="&xsd;string">05</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: Agency funded by the State Government to perform tasks on behalf of the State. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StationPrivate -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StationPrivate">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">04</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A point on a privately owned and operated railway designated as a stopping place to set down or pick up passengers. These are generally tourist railways and do not run a schedule for commuters. Eg. Kangaroo Flats Station (in Whiteman Park)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StationPublic -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StationPublic">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RailFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">03</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A point on a railway designated as a stopping place to set down or pick up passengers on a regular schedule. (Modified ICSM)
This is the default for RailFacilityPOIType.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SteelRollingMill -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SteelRollingMill">
<rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
<domain_code rdf:datatype="&xsd;string">17</domain_code>
<rdfs:isDefinedBy xml:lang="en">Definition: A plant where pig iron is converted into steel. Steel mills also turn molten steel into blooms, ingots, or slabs through hot rolling and continuous casting.</rdfs:isDefinedBy>
```

```
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StudentResidentialFacility -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#StudentResidentialFacility">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationSupportDomain"/>
    <domain_code rdf:datatype="&xsd;string">12</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility for accommodating students; associated with a specific institution and providing full board lodging. (WA) eg. St Catherine’s College, Currie Hall.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Supermarket -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Supermarket">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutletDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A large self-service retail store that sells a wide range of food and household goods. (WA)
This is the default for RetailOutletPOIType.</rdfs:isDefinedBy>
    <isSubclassOf rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RetailOutlet"/>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Surfing -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Surfing">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#SportingFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">06</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A location favoured by surfers for the characteristics of its break. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Swamp -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Swamp">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">07</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A named swamp-like landform. Includes: Swamp and Marsh.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Synagogue -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Synagogue">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceOfWorshipDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A Jewish house of prayer. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TAFE -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TAFE">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
    <domain_code rdf:datatype="&xsd;string">07</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used for providing education or instruction in technical, business or trade subjects at a
post-secondary level. (NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TavernAndBar -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TavernAndBar">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LicensedPremisesDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An establishment licensed to sell alcoholic beverages to be consumed on the premises.
This is the default LicensedPremisesPOIType.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TaxiRank -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TaxiRank">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BusFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A designated area where taxis park while awaiting passengers. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telecentre -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telecentre">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#CulturalFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">08</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A local community centre equipped with high tech facilities. A typical Telecentre has computers
the Internet and email facilities, two-way 128kb videoconferencing, photocopiers, fax machines, printers TV and video machines, decoders, scanners and more depending on the needs of the community. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telecommunication -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telecommunication">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MediaAndTelecommunicationDomain"/>
    <domain_code rdf:datatype="&xsd;string">03</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Business organisations associated with the transmission of information by electromagnetic signals. (WA). Eg. Iinet.
This is the default for MediaAndTelecommunicationPOIType.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telephone_Emergency -->
```

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    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telephone_Emergency">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmenityDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Telephone installed/configured for emergency use only. (WA)
This is the default AmenityPOIType.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telephone_Public -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Telephone_Public">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmenityDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Telephone installed for public use. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TelevisionBroadcasting -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TelevisionBroadcasting">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#MediaAndTelecommunicationDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Location of the offices and studios from which programs are produced and broadcast for
viewing via television. (WA) eg. ABC.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TheatreAndConcertHall -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TheatreAndConcertHall">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EntertainmentVenueDomain"/>
        <domain_code rdf:datatype="&xsd;string">18</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A building, room or area expressly designed to house dramatic presentations, stage
entertainments, or musical performance. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ThemePark -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ThemePark">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmusementDomain"/>
        <domain_code rdf:datatype="&xsd;string">19</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An amusement park in which landscaping, buildings, and attractions are based on one or more
specific themes, as jungle wildlife, fairy tales, convict settlement, etc.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Toilet -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Toilet">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AmenityDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A structure with fixtures that consists usually of a water-flushed bowl and seat and is used for
defecation and urination. (Modified Merriam-Webster Dictionary)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Tourism -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Tourism">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RecreationType"/>
        <subtype_code rdf:datatype="&xsd;string">08</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Features and services of particular interest to travellers. (WA)
Spatial Representation: A single point at the feature’s main entrance or at the feature’s central
point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristAttraction -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristAttraction">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain"/>
        <domain_code rdf:datatype="&xsd;string">02</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A man made feature expressly designed to attract and entertain tourists. (WA) For example:
Perth Wheel.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristInformationBay -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristInformationBay">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A roadside area usually located on a main access route to and on the outskirts of, a town with
billboards providing information regarding the local area specifically for tourists. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristInformationCentre -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristInformationCentre">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain"/>
        <domain_code rdf:datatype="&xsd;string">04</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A public service providing tourist information. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristSite -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TouristSite">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TourismDomain"/>
        <domain_code rdf:datatype="&xsd;string">05</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A place of significance to tourists. The POI feature is representative of the complex of
facilities
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provided to service tourists. For example: Circular Pool.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Town -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Town">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PlaceDomain"/>
        <domain_code rdf:datatype="&xsd;string">03</domain_code>
        <rdfs:isDefinedBy rdf:datatype="&xsd;string">Definition: A compact settlement larger than a village, with a community pursuing an urban way of life. (CGNA)
This is the default for PlacePOIType. </rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TrafficAndVehicleLicensingCentre -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TrafficAndVehicleLicensingCentre">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GovernmentDomain"/>
        <domain_code rdf:datatype="&xsd;string">06</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Department of Transport public contact centre for matters to do with vehicles including registration, driver licensing, vehicle inspections and related matters. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationPOI -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationPOI">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#POIClass"/>
        <class_code rdf:datatype="&xsd;string">06</class_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: Facilities and service features related to transportation. (WA)
Spatial Representation: A single point at the feature’s main access point where applicable, otherwise at the feature’s central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Tunnel -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Tunnel">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#TransportationType"/>
        <subtype_code rdf:datatype="&xsd;string">07</subtype_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A passage through or under a barrier.(WA)
Spatial Representation: A single point at the feature’s main entrance or central point.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#UnexplodedOrdnanceService -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#UnexplodedOrdnanceService">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
        <domain_code rdf:datatype="&xsd;string">09</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A state emergency management service charged with the search for and neutralisation
of any explosive ordnance (ammunition, bomb grenade, torpedo etc) that has failed to function as intended, from land intended for development.</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#University -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#University">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#InstitutionDomain"/>
        <domain_code rdf:datatype="&xsd;string">08</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility for conduction teaching and research at a diploma, undergraduate or postgraduate level. (NSW)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ValveStation -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ValveStation">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">18</domain_code>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#VolunteerBushFireBrigade -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#VolunteerBushFireBrigade">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EmergencyServicesDomain"/>
        <domain_code rdf:datatype="&xsd;string">10</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A group of volunteers managed by the local government authority and supported by
FESA to provide fire fighting services as required. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Warehouse -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Warehouse">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">26</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A building for the storage for goods and merchandise. (Modified Web)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WasteDisposal -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WasteDisposal">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
        <domain_code rdf:datatype="&xsd;string">35</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A facility such as a rubbish tip used to deal with rubbish and waste. (WA)</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WasteWaterProcessingPlant -->
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<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WasteWaterProcessingPlant">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">19</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used to treat waste water.(Modified NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeature -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeature">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#GeographicType"/>
    <subtype_code rdf:datatype="&xsd;string">02</subtype_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Topographic featuresof significance whose primary characteristics relate to waters. (WA)
Spatial Representation: A single point at the feature’s central point.</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterProcessingPlant -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterProcessingPlant">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#IndustrialFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">20</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility used to treat drinking water.(Modified NSW)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Waterfall -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Waterfall">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WaterFeatureDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A sudden descent of water over a step or ledge in the bed of a watercourse. (AUSLIG)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Weighbridge -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Weighbridge">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#RoadFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">02</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A platform scale flush with a roadway for weighing vehicles. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Wharf -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Wharf">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ShippingFacilityDomain"/>
    <domain_code rdf:datatype="&xsd;string">05</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Any structure on a waterfront, designed to make it possible for vessels to lie alongside
and take or unload cargo, passengers etc. (ICSM)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Winery -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Winery">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#LicensedPremisesDomain"/>
    <domain_code rdf:datatype="&xsd;string">04</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An establishment at which wine is made that incorporates a cellar door providing wine tasting
and sales to the public. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Women -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Women">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#HospitalDomain"/>
    <domain_code rdf:datatype="&xsd;string">09</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A facility that specialises in the medical care of women. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WorkersUnion -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#WorkersUnion">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain"/>
    <domain_code rdf:datatype="&xsd;string">06</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: A group of workers who have banded together to achieve common goals such as
improved working conditions. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#YouthAndBackpackerHostel -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#YouthAndBackpackerHostel">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#AccommodationDomain"/>
    <domain_code rdf:datatype="&xsd;string">09</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: Budget priced accommodation facility providing dormitory or communal style lodging and
generally requiring guests to provide their own bed linen (sleeping Bags).</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#YouthOrganisation -->
<owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#YouthOrganisation">
    <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#OrganisationDomain"/>
    <domain_code rdf:datatype="&xsd;string">07</domain_code>
    <rdfs:isDefinedBy xml:lang="en">Definition: An organisation set up to provide young people within an area with activities designed
to keep them off the streets, help give them a job and develop an interest in activity. (WA)</rdfs:isDefinedBy>
</owl:NamedIndividual>

<!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ZoologicalGarden -->
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    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#ZoologicalGarden">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BotanicalAndZoologicalDomain"/>
        <domain_code rdf:datatype="&xsd;string">19</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: An area with a collection of live animals usually for public display. (DIGEST)
This is the default for BotanicalAndZoologicalPOIType
</rdfs:isDefinedBy>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#bridge -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#bridge">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#BridgeDomain"/>
        <domain_code rdf:datatype="&xsd;string">01</domain_code>
        <rdfs:isDefinedBy xml:lang="en">Definition: A structure spanning and providing passage over a depression or obstacle. (WA)
This is the default for BridgePOIType.</rdfs:isDefinedBy>
        <rdfs:comment xml:lang="en">Start with lower case to avoid conflict with subtype &quot;Bridge&quot;</rdfs:comment>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#poi_427 -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#poi_427">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
        <latitude rdf:datatype="&xsd;decimal">-32.051666</latitude>
        <classificationCode rdf:datatype="&xsd;string">020103</classificationCode>
        <longitude rdf:datatype="&xsd;decimal">115.89778</longitude>
        <name rdf:datatype="&xsd;string">ROSTRATA PRIMARY SCHOOL</name>
        <locality rdf:datatype="&xsd;string">WILLETTON</locality>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#poi_8035 -->
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#poi_8035">
        <rdf:type rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PointsOfInterest"/>
        <latitude rdf:datatype="&xsd;decimal">-33.35766</latitude>
        <longitude rdf:datatype="&xsd;decimal">115.63457</longitude>
        <name rdf:datatype="&xsd;string">ADAM ROAD PRIMARY SCHOOL</name>
        <roadName rdf:datatype="&xsd;string">HOTCHIN</roadName>
        <locality rdf:datatype="&xsd;string">SOUTH BUNBURY</locality>
        <roadType rdf:datatype="&xsd;string">ST</roadType>
        <hasPOIClass rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#EducationPOI"/>
        <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Institution"/>
        <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrimarySchool"/>
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    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#poi_8058 -->
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        <roadType rdf:datatype="&xsd;string">AV</roadType>
        <locality rdf:datatype="&xsd;string">BULL CREEK</locality>
        <roadName rdf:datatype="&xsd;string">EWING</roadName>
        <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-
53#CombinedPrimarySecondary"/>
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        <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Institution"/>
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    <!-- http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#poi_8117 -->
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        <longitude rdf:datatype="&xsd;decimal">115.937338</longitude>
        <houseNum rdf:datatype="&xsd;string">176</houseNum>
        <roadName rdf:datatype="&xsd;string">ANZAC</roadName>
        <name rdf:datatype="&xsd;string">ANZAC TERRACE PRIMARY SCHOOL</name>
        <locality rdf:datatype="&xsd;string">BASSENDEAN</locality>
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        <roadType rdf:datatype="&xsd;string">TCE</roadType>
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        <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Institution"/>
        <hasPOIDomain rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#PrimarySchool"/>
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        <longitude rdf:datatype="&xsd;decimal">115.8984</longitude>
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        <name rdf:datatype="&xsd;string">ROSTRATA PRIMARY SCHOOL</name>
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        <hasPOISubtype rdf:resource="http://www.semanticweb.org/15569431/ontologies/2015/2/untitled-ontology-53#Institution"/>
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//
// Rules
//
///////////////////////////////////////////////////////////////////////////////////////
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                                  <swrl:argument2 rdf:resource="urn:swrl#str1"/>
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53#PointsOfInterest"/>
          <swrl:argument1 rdf:resource="urn:swrl#p"/>
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53#subtype_code"/>
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<!-- Generated by the OWL API (version 3.4.2) http://owlapi.sourceforge.net -->
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